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Aerodynamic Stability Technology for Maneuverable Missiles. Vol. II. Asymmetric Vortex Effects Computer Program

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A procedure for estimating the effects of	
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FOREWORD

This report was prepared for the U.S. Air Force Flight Dynamics Laboratory, Wright-Patterson Air Force Base, Ohio, under Contract Number F33615-75-C-3052.

The work reported herein was performed at the Orlando Division of Martin Marietta Aerospace as a part of Project 8219, "Stability and Control for Aerospace Vehicles", Work Unit 82190117, "Aerodynamic Stability Technology for Maneuverable Missiles".

This work was performed during the period February 1975 to December 1976.

The principal investigators were J. E. Fidler and G. F. Aiello. The technical monitor for AFFDL was Mr. William H. Lane.



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LIST OF SYMBOLS

A ,	Reference area
a	Body radius
AR	Tail aspect ratio
C _A	Axial force coefficient
c _{dc}	Crossflow drag coefficient
CETAMC	Yawing moment coefficient
$\mathbf{c_L}$	Lift coefficient
C.	Rolling moment coefficient
C _N	Normal force coefficient
C _n	Yawing moment coefficient
C _Y	Side force coefficient
đ	Missile body diameter
è	Axial extent of base influence
F	Vorticity flux
8	Axial distance over which boundary layer is shed to form vortex
h	Vortex street lateral dimension
K	Coefficient in vortex strength equation
1	length
2	Vertical distance between vortices of like sign
М	Mach number
m	Number of vortices in wake at a given axial location on the body
n	Frequency with which vortices of like sign are shed
p ,	Spanwise distance from tail root to tip
Ī.	Radial limit of vortex influence on a body

LIST OF SYMBOLS (CONT'D)

R _e	Reynolds number
r	Radial distance from center of body
S	Strouhal number = nd/Vsina
ប _ន	Circumferential velocity at edge of boun ary layer at separation
v	Freestream velocity
v	Velocity induced normal to tail leading edge in the y direction
x	Axial distance along body
Y	Side force
у	Lateral distance normal to body axis
z .	Distance above and normal to body axis
α ,	Angle of attack
δ	Nose hald angle
σ	Angle between growing vortex cores and body axis
θ _s	Circumferential separation point angular orientation
ξ	Angle between street vortex cores and body axis
r	Vortex strength
Γ(x)	Local value of strength in a growing vortex
r/Vdsina	Vortex dimensionless strength parameter
ρ	Freestream density
Φ '	Roll angle
x	Separation angle parameter
λ	Tail taper ratio

SUBSCRIPTS

8	Axial direction
В	Body
c	Crossflow
Ĺ	Induced, vortex indicator
L, R	Left and right sides of body, respectively
·	Initial condition
3	Denotes vortices, starting with third from missile nose
ŗ	Tail
K .	Denotes conditions at axial station x
l, 2	First and second vortices, respectively

SUMMARY

A computerized engineering model is presented for estimating the effects of asymmetric lee-side vortices on slender missile configurations. The procedure was developed using both empirically determined quantities and t'eoretical techniques. Empirical inputs define both vortex locations and street vortex strengths; whereas, potential flow considerations guide in the definition of initial vortex strengths and induced forces and moments. The procedure is applicable to bodies with and without tails. Calculable effects are: induced side forces, yawing moments, tail forces, and rolling moments. The procedure was applied to a number of different combinations of geometries and flow conditions and the results compared against experimental data. These comparisons, while not exact, have shown the procedure to be suitably accurate for preliminary design purposes. Using this procedure, a user can estimate the magnitude but not necessarily the direction of vortex induced forces and moments and the angle of attack at which they first appear. Uncertainty in direction is attributed to the randomness associated with formation and subsequent shedding of the initial pair of vortices. Nose geometry irregularities greatly influence the side of the body from which the initial vortex separates.

A users manual for this computerized procedure is also provided. The manual includes user instructions, a program listing, sample inputs, and sample outputs.

1.0 INTRODUCTION

In recent years, increased maneuverability requirements for air-to-air missiles have dictated corresponding increases in angles of attack, particularly for those vehicles which perform slewing maneuvers. Maximum angles for such missiles can now reach 180 degrees. As a result of these developments, the flow fields with which the aerodynamicist has to deal are much more complex, and traditional methods for predicting aerodynamic characteristics are inadequate to deal with all the problems involved. One example of method deficiency is found in the angle of attack range 25-50 degrees.

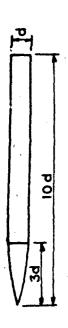
Here, steady, asymmetric vortex patterns usually develop in the body wake and can induce large side forces and yawing and rolling moments which are detrimental to missile controllability. Few methods are currently available for predicting these forces and moments or for analyzing the complex flow fields which produce them. The effects are particularly scute in the subsmic-transonic speed range. At Mach numbers greater than about 1.5, however, they tend to diminish rapidly.

The flow phenomena involved and their effects have received considerable attention recently, (1-9) although wake vortex effects and asymmetry have been reported by earlier authors. (10-13) Among the earliest studies were those of Allen and Perkins (10) and Perkins and Jorgensen, (11) in which some of the basic flow structure in the wake was investigated and the onset of vortex asymmetry observed. More recent work by Thomson and Morrison (1) and Thomson (2,8) determined details of the wake flow field and the associated vortex characteristics through direct flow probing. In that work, attention was drawn to the strong similarities between the three-dimensional asymmetric wake and its two-dimensional counterpart, the von Karman vortex street.

Heasurements were made of vortex strengths, spacing and shedding frequency. The dats of Reference 1 have often formed the basis for follow-on work to determine vortex effects on slender missiles (5,8) or for the computation of wake flow characteristics. (6) The measurements form part of the basis for the present work, with suitable modifications for various flow parameter changes.

Recent wind tunnel investigations performed by Martin Marietta showed marked evidence of asymmetric vortex effects. The magnitudes of typical induced quantities are shown in Figures 1 and 2. In Figure 1, pitch and yaw plane moment data up to 60 degrees angle of attack are shown for an isolated body composed of an ogive-Cylinder of 10:1 total slenderness ratio. Beginning around 25 degrees angle of attack, considerable yawing moments were induced due to asymmetries. The addition of tails to the body (Figure 2) results in the generation of yawing moments which are almost as large as the pitching moments. In addition to the problem of magnitudes is that of unpredicatable sign. (1,3,4) Random changes in direction of forces and moments have been observed, sometimes related to changing flow conditions, but often interpreted to be caused by small manufacturing imperfections near the missile nose (1,3,4). In fact, significant changes in induced force and moment magnitudes and signs can be produced by rotation of all or parts of the body. (1,3,4) This has further, serious implications for missile controllability.

It is clear that techniques are required for calculating the forces and moments induced by asymmetric vortex wakes. Some work has already been done in this area (8,9) for slender bodies at subcritical crossflow Reynolds number. The procedure presented in this document deals with that case also, but goes further in considering supercritical crossflow Reynolds and Mach



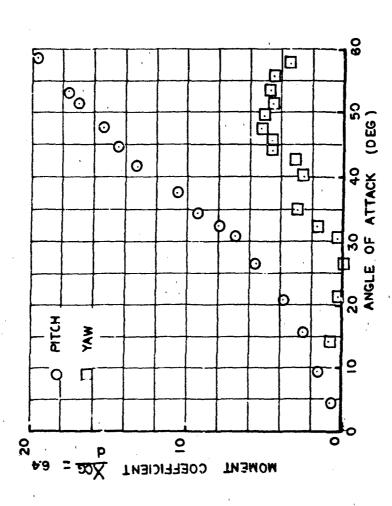


FIGURE I COMPARISON OF PITCH AND YAW MOMENTS (1SOLATED BODY M=QB)

number effects for bodies with and without tails. This technique is semi-empirical, drawing upon the experimental evidence referred to above, but modifying it for different flow conditions and supplementing it with analytical results and techniques. To make this technique more readily useable, it has been programmed for digital computation.

The layout of this document is as follows: first, a general description of the flowfield is presented, followed by descriptions of the techniques used to model the asymmetric vortex wake and calculate the induced forces and moments. Following these, there is a section presenting comparisons between predicted results and experimentally measured data. Finally, there is the information necessary to operate the program, i.e., user instructions, a program flow chart and listing, sample inputs/outputs and an indication of program limitations.

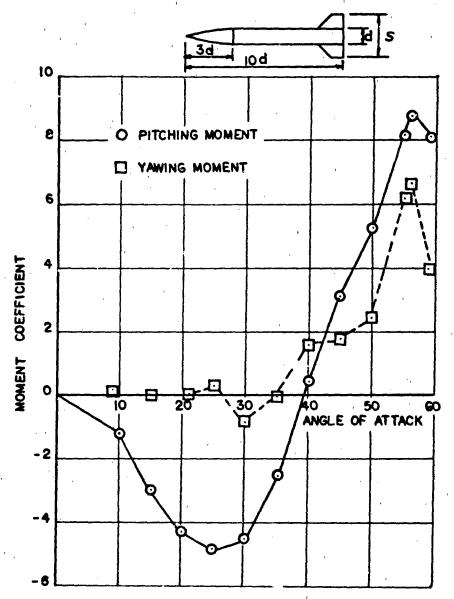


FIGURE 2 COMPARISON OF PITCHING AND YAWING MOMENTS (BODY-TAIL M=0.8)

2.0 FLOWFIELD DESCRIPTION

When a slender missile body is placed at angle of attack in a uniform flow, the boundary layer generally separates on either side of the body and forms a lee side wake. Separation usually begins near the rear when the missile reaches about 6 degrees angle of attack. The wake takes the form of a pair of symmetrically-disposed, counter-rotating vortices fed by vorticity shed from the separating boundary layer. As angle of attack increases the axial extents, sizes and strengths of the vortex increase also.

In general, vortex size and strength also increase towards the rear of the body. Several authors have formulated descriptions of vortex development along slender bodies in terms of two-dimensional, impulsively-started flows around cylinders. These formulations relate flow development with time, measured either from the beginning of impulsive two-dimensional motion or from the instant a fluid particle makes contact with a three-dimensional body. In the latter case, time is defined by distance travelled along the body and the axial component of freestream velocity. For the two-dimensional case, the motion of the vortex cores as time passes (i.e., vortex size and strength increase) theoretically follows a path known as the Föppl line. (14) Use has been made of this result in the present work, as will be described later.

When the body angle of attack reaches about 25 degrees, the symmetric nature of the wake disappears. The two vortices are joined by a third, beginning again at the body rear, and the wake becomes asymmetric. As angle is increased further, more vortices join the flow until the wake contains several which have been shed from the body. An idealized model of the flow field is shown in Figure 3. A section taken through the wake shows

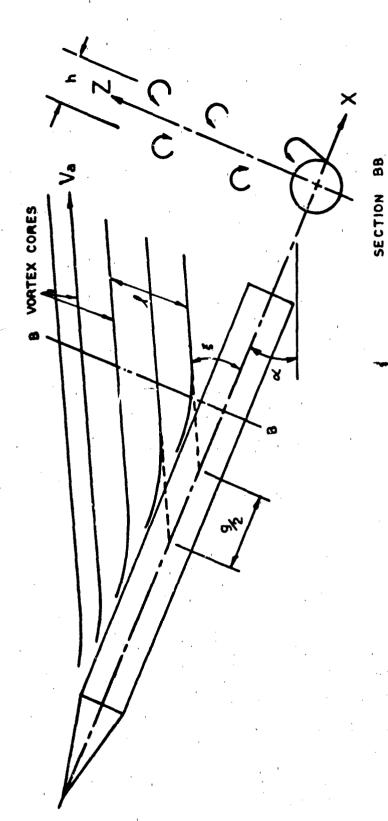


FIGURE 3 SCHEMATIC OF LEE SIDE VORTEX PATTERN

7

it to resemble the von Karman vortex street, well known in the literature on two-dimensional flows. Not all of the vortices are fully shed, however; two usually remain close to the body, receiving vorticity from the shedding boundary layers. If angle of attack continues to increase these, too, will be fully shed into the wake when their strength reaches some critical value. Their places will be taken by yet other growing vortices.

While a growing vortex is receiving vorticity from the boundary layer, i.e., before it reaches full strength, it tends to stay close to the body. Thomson and Morrison (1) showed schlieren photographs which implied that the vortex core is somewhat curved while it is forming. Not until full strength has been reached does the core become straight and parallel to the rest of the vortices in the street. This core behavior is indicated in Figure 3.

It has been determined that a marked similarity exists between the manifestations and effects of two- and three-dimensional asymmetric vortex wakes. (1) In fact, the von Karman street stability criterion that the ratio of lateral street dimension, h, to the distance between vortices of like sign, £, given by h = 0.281£, has been shown to apply to both cases (Figure 3). However, in the wake of Figure 3 no lateral motion of the vortex cores relative to the body takes place. The two-dimensional phenomenon of increasing distance between vortex core and body as time increases is analogized in the same way as for the symmetrical vortices. That is to say, the wake is steady and the motion of a fluid particle along a (stationary) vortex core may again be described in equivalent time by its axial velocity and distance traveled. Through use of this analogy, Thomson and Morrison (1) were able to deduce the strengths of asymmetric wake vortices as well as their effects upon body crossflow drag. Thomson (8) recently extended this work to deal with induced side forces and yawing moments on bodies at subcritical crossflow Reynolds numbers.

At still higher angles of attack, say greater than 50 degrees, the wake begins to display unsteadiness. The vortex cores show definite lateral displacements relative to the body and the induced forces and moments become time-dependent. The procedure presented in this document does not consider this case. Attention is directed only to the phenomena in the angle of attack range from 25 to 50 degrees and their effects upon missile aerodynamic characteristics.

3.0 CONSTRUCTION OF FLOW FIELD MODEL

Development of a procedure to predict the effects of an asymmetric vortex wake on configuration aerodynamics requires the development of a realistic flow field model. A flow field model, reflecting the state-of-the art, can be developed using semi-empirical inputs based on the data of References 1, 2, 8 and 16 and theoretical results (14,15)

Vortex strengths and locations have been made compatible with the findings of Reference 1 and suitably scaled to broaden their ranges of applicability. In addition, theoretical results on the locations of wake vortices and their images have been introduced and the contribution of nose potential lift to vortex strength has been considered. Both shed and growing vortices are treated, making use in part, of a vorticity-conservation concept. (6) Each of the above components of the model is described in detail beginning with vortex strength.

Vortex Strength

Detailed flow surveys have shown (1,8) that not all the wake vortices are of the same strength. Generally, the first vortex from the nose originates near the nose/body junction and has the smallest strength in the wake, Γ_1 , say. The second vortex separates soon after the first and has a somewhat higher strength, Γ_2 . From the third vortex onwards, all have approximately the same strength, $\Gamma_{\rm S}(>\Gamma_2)$, and their spacing and strength are analogous to those of the vortices in a von Karman street. While the first and second vortex strengths will contain contributions from the (potential) nose lift, the "street" vortices are wholly fed with vorticity from the separating body boundary layer. Reference 8 presents detailed information on dimensionless vortex strength, $\Gamma_{\rm S}$, for various angles of attack at subcritical crossflow Reynolds number. For the first two vortices, strength is calculated using concepts from potential flow theory.

The first and second vortex strengths must contain a contribution from the potential flow lift of the nose. The strength of the first vortex, Γ_1 , may be estimated if it is assumed that the nose is replaced by a horizontal lifting line of constant strength, Γ_1 located at the nose/body junction (Figure 4). All of the nose lift is assumed generated by this line and the associated trailing vortices will have its strength provided they receive no further vorticity, from the shedding boundary layer for example. The first vortex shed, near the nose body junction, will probably contain only potential-flow-generated circulation. To calculate vortex strength Γ_1 is straight forward. It can be shown (15) that the coefficients of normal and axial force acting on the nose are predicted by slender body theory to be:

 $C_N=2\sin\alpha$ and $C_A=C_A-\sin^2\alpha$ where the reference area is that of the body cross section. Converting these quantities to lift coefficient yields

$$C_L = C_N \cos \alpha - C_A \sin \alpha$$

If C_{A_0} is assumed negligible (as it will be, compared to the axial forces generated at the high angles of attack here) this expression becomes after some manipulation

$$L = \frac{\rho}{8} V^2 \pi d^2 (2 \sin \alpha \cos \alpha + \sin^3 \alpha)$$
$$= \rho \Gamma_1 dV$$

The latter expression is the well-known Kutta-Joukowski theorem. Finally, the equation may be rearranged to yield:

$$\frac{\Gamma_1}{Vd \sin \alpha} = \frac{\pi}{8} (2 \cos \alpha + \sin^2 \alpha) \tag{1}$$

This dimensionless vortex strength may be compared with measurements from flow field surveys. (1) Using an angle of 30 degrees, equation (1) yields a dimensionless strength of 0.78. The corresponding measured strengths

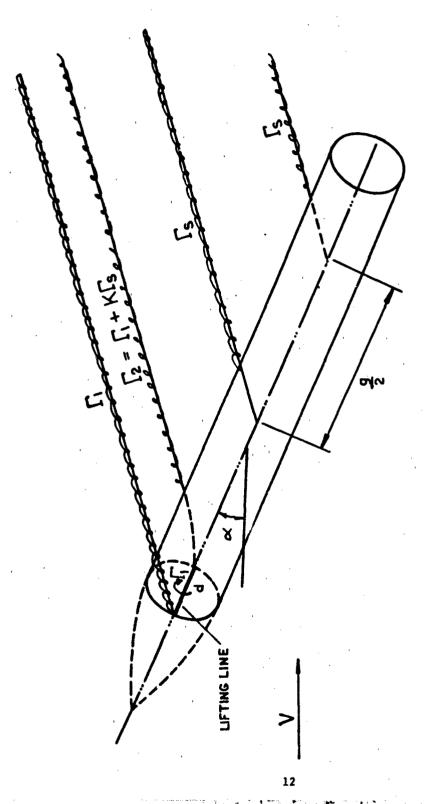


FIGURE 4 SCHEMATIC OF FLOWFIELD MODEL

from Reference 1 show a range of values from 0.3 to 1.1 with a mean value of 0.7. This compares quite well with the predicted value. Where it is found that the first vortex is shed forward of the nose/body junction, its strength is simply determined by using the local nose diameter in equation (1).

There should be little or no effect of Reynolds number on Γ_1 since the strength is determined by potential flow considerations. On the other hand, Γ_s is wholly produced by visous flow and is strongly affected by crossflow Reynolds number (R_e) , which influences the characteristics of the boundary layer shed to form the street vortices. The second vortex, being shed downstream from the nose/body junction, is modeled here as a "mixed vortex," i.e., a potential flow vortex which receives additional vorticity from the shedding boundary layer just aft of the nose (Figure 4). Formally, Γ_2 is expressed as:

$$r_2 = r_1 + \kappa r_s$$

K was found empirically to be about 0.22 from the wake survey data of Reference 1.

For street vortex strength at subcritical R_e , the data shown in Figure 5 were used $^{(8)}$. In order to scale Γ_s for supercritical R_e , use was made of von Karman's result $^{(14)}$ that crossflow drag coefficient, C_{dc} , is approximately proportional to the street vortex strength, Γ_s (the expression for C_{dc} contains terms in Γ_s and $\Gamma_s^{(2)}$; however, the latter accounts for less than 10 percent of the total; hence, C_{dc} is approximately proportional to Γ_s). Data obtained from Martin Marietta investigations into crossflow drag $^{(16)}$ produced the information of Figure 6, which shows that for low crossflow Mach number, crossflow Reynolds number has a strong influence on crossflow drag. Above the critical crossflow Reynolds number (about 10^5), C_{dc} shows a significant decrease below the subcritical value. Hence, Γ_s , too, will be significantly reduced. An increase in crossflow Mach number, M_c , is required to increase both C_{dc} and

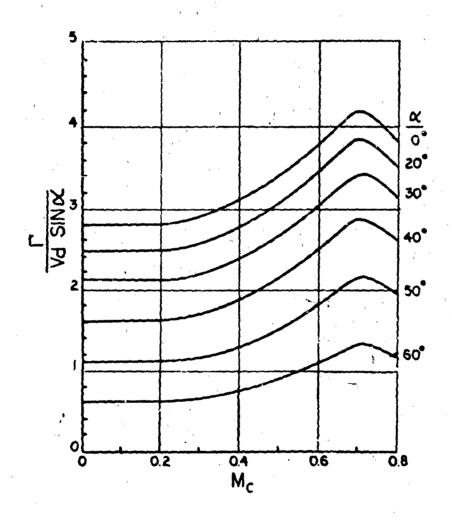
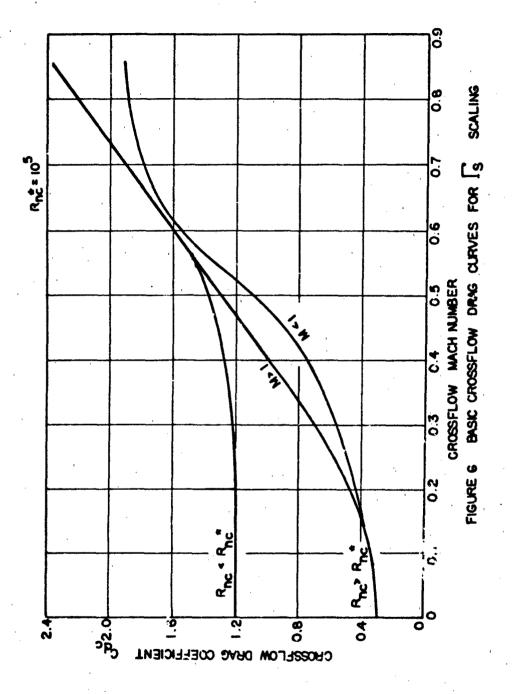


FIGURE 5 VORTEX STRENGTH PARAMETER SUB-CRITICAL Rec



 $\Gamma_{\rm s}$. Accordingly, for R $_{\rm e_{\rm c}}$ > 10 5 the subcritical R $_{\rm e_{\rm c}}$ values of $\Gamma_{\rm s}$ from Figure 5 are scaled in the same ratio as $C_{\rm dc}$ from Figure 6.

In order to illuminate further the mechanisms underlying the relationship between crossflow Reynolds number and vortex strength, recent work by Fidler $^{(6)}$ will be briefly described. It may be shown that the strength of a lee side asymmetric vortex can be related to the flux of crossflow vorticity leaving the body at the circumferential separation point defined by $\theta_{\rm g}$. Further, the vorticity flux shed over axial distance g (at fixed angle of attack) in unit time is:

$$F_{\mathbf{g}} = \text{const} \int_{0}^{\mathbf{g}} U_{\mathbf{s}}^{2} dx$$

The vorticity thus shed diffuses through the vortex to produce the circulation $\Gamma_{\bf s}$. Equating the flux ${\bf F}_{\bf B}$ to that flowing along a wake vortex of core velocity ${\bf V}_{\bf s}$ yields an expression for vortex strength:

$$r_s = \frac{\text{const}}{v_a} \int_0^8 u_s^2 dx$$

Now U_g , the circumferential velocity at the boundary layer edge at separation, is a function of θ_g . In the two-dimensional case (17) it has been found experimentally that when crossflow Reynolds number is subcritical, θ_g lies near the meridian of the cylinder and the associated separation velocity U_g is larger than in the supercritical Reynolds number case, where the separation point lies far over on the cylinder lee side. Continuing the analogy between two and three dimensions indicates that crossflow Reynolds number affects Γ_g through its effects; first upon θ_g , which in turn determines U_g which defines the vorticity flux flowing from the body and diffuses through the vortex to produce Γ_g . Hence, subcritical R_g produces larger Γ values than does supercritical R_g , provided crossflow Mach number is low.

The foregoing discussions deal with fully-developed voluces which have left the immediate vicinity of the body and joined the asymmetric wake pattern. However, consideration must be given to the street vortices while they are forming close to the body. As previously discussed, these growing vorticies are fed by vorticity from the separating body boundary layer. Assuming rapid diffusion of vorticity the local vortex strength $\Gamma(x)$ formed by shedding a boundary layer over distance x may be written (see previous equation).

$$\Gamma(x) = const \int_{0}^{x} U_{s}^{2} dx$$

Furthermore, it has been experimentally determined $^{(4)}$ that for those portions of the body where street vortices are being formed and for given flow conditions, the circumferential location of boundary layer separation, θ_s , is approximately constant with x. Hence, U_s , the circumferential velocity at the boundary layer edge at separation is also constant. Thus the local vortex strength is seen to be directly proportional to x, i.e.,

 $\Gamma(x) = \Gamma_s x/g$ where g is the distance over which boundary layer fluid is shed to form a street vortex.

One final item affecting the strengths of forming vortices has been considered. It has been shown by Thomson (8) that as a growing vortex nears the base of the body, the rate at which its strength increases is reduced due to base proximity. Thomson's data indicate that the growth rate is only 40 percent of normal. The axial extent of the region over which the base influence is felt is given by

$$e = \frac{d^2}{2 S \ell \tan \alpha}$$

The model contains this feature.

At any body axial station, then, the strengths of all the vortices

are calculable from the combined theoretical/empirical procedures described above. The next stage in flow field model construction is to locate the vortices relative to the body so that their effects may be calculated.

Vortex Location and Spacing

The problem of locating vortex cores in space relative to the body must be handled separately for vortices growing near the body (i.e., those being fed with vorticity from the separating boundary layer) and for shed vortices which can be considered part of the wake street. In the former case, use is made of theoretical results from two-dimensional potential flow theory; in the latter, systematic experimental evidence, suitably scaled for flow parameter changes, is employed. The case of growing vortices will be described first.

Growing Vortices

In order to model the trajectory followed by a growing vortex, two reference points are required. The first is the circum erential location on the body at which the boundary layer separates. The second is the point in space at which the vortex has reached full strength and can be said to have joined the street.

The first point is located by the empirical relationship

$$\theta_s = \sin^{-1} (3 \tan \delta/2 \tan \alpha)$$

The angle thus defined places separation in the general region typical of laminar/turbulent boundary layers. Since the means of determining vortex strength does not rely upon an exact knowledge of the separation point location, the above approximation is sufficient for present purposes. If the determination of vortex strength had required use of the Kutta condition, or some estimate of vorticity flux leaving the body, the angle

 $\theta_{\rm g}$ would have been required with some accuracy. In the present method however, vortex strength is defined otherwise and a rough estimate of the separation angle is sufficient.

The second point for anchoring the growing vortex trajectories was taken as the intersection of the Foppl and von Karman lines along which the symmetric and asymmetric vortex cores were known to move respectively. Use of this point was justified as follows:

As discussed earlier, the appearance of vortices in the wake shows, at the earliest stage, a symmetric pair. At any axial station, increasing angle of attack produces increased vortex size and strength as well as an outward movement of the core approximately following the Foppl line. It was reasoned that at the first appearance of asymmetry, one of the vortices on the Foppl line would change its trajectory and proceed outwards along a new path defined by the von Karman stability relationship described earlier. The second vortex would perform similarly and this would then set up the spacing of vortices in the street. It was hypothesized then, that in order to continue the spacing pattern, the intersection of the Foppl and von Karman lines would denote the point at which all vortices reached full strength and were shed into the street. In order to test this hypothesis the schlieren photographs of Thomson and Morrison (1) were examined to determine the distance from the body where vortex feeding from the boundary layer ceased, i.e., the point at which the growing vortex cores became straight and joined the street. It was found that the points thus defined covered a band of values from 2 to 2.5 diameters above the body and at a lateral distance defined by the von Karman stability criterion. To determine the theoretical location of the shedding point, the following procedure was used. With the equation, (14), $2 \text{ ry} = r^2 - a^2$,

the Foppl line was drawn relative to the cylinder of Figure 7. The data of Reference 1 were used in the equation $d/\ell = S/\chi$ to determine ℓ , the spacing between street vortices of like sign for subcritical crossflow Reynolds numbers. Then the von Karman relation $h = 0.281\ell$ was used to superimpose the street vortex location line on Figure 7. The intersection of the Foppl and von Karman lines was found to lie within the experimentally-determined range given above. It was concluded then, that this intersection point provided a good estimate of the location at which the vortices stopped growing and were shed to form part of the street. For the purposes of this engineering flow model the growing vortex core was assumed to move linearly between the two anchor points. The resulting core trajectory model is shown (foreshortened) in Figure 8.

Street Vortices

From the Foppl/von Karman line intersection the vortex cores stream back into the wake as straight lines, making angle ξ with the body axis. This angle was measured by Thomson and Morrison, (1) related to the rate at which a fluid particle flowing along the core increases its distance from the body, and thence analogized to the two-dimensional von Karman street. ξ is related to missile angle of attack through the parameter χ = tan $\xi/\tan\alpha$ (1). If the point on the body from which a vortex emanates is known, then its core location in space may be partly determined using χ . For the purposes of this work χ was assumed unaffected by changes in cross-flow Reynolds number.

Vortex starting points on the body were estimated in Reference 1 as being the intersection point of the body axis and the extrapolated street vortex cores. Since these positions were obtained for tailless bodies, the

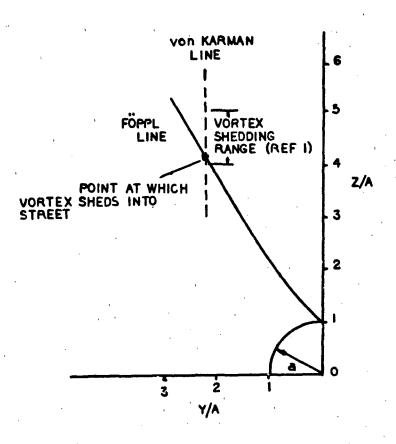


FIGURE 7 COMPARISON BETWEEN PREDICTED AND EXPERIMENTAL POINT WHERE VORTEX IS SHED INTO STREET

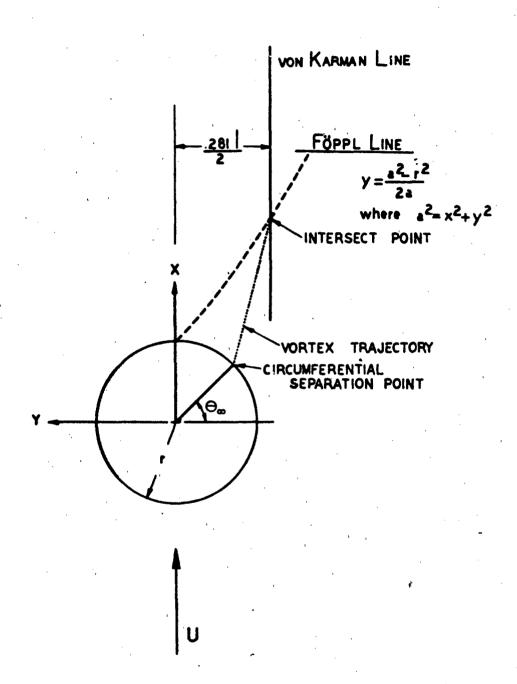


FIGURE 8 GROWING VORTEX'S TRAJECTORY

present work assumes that in the presence of tails, body vortex formation ceases at the body/tail leading edge intersection. Provided the Strouhal number, S, is known, the starting points of wake vortices can be determined. Further, using the relation (1) $d/t = S/\chi$, the lateral spacing, t, between vortices of like sign, and hence 0.281t, the von Karman-deduced criterion for lateral spacing can be determined. The vortex cores can now be located in space relative to the body at any point along their lengths. At this stage, however, the information is sufficient only for subcritical cross-flow Reynolds numbers.

The quantity on which attention must be concentrated when scaling vortex locations for crossflow Reynolds number is the Strouhal number, S. This measure of the rate at which vortices of like sign are shed from the body has been shown to exhibit strong similarities between the two- and threedimensional cases. In Reference 1, S was determined experimentally to have values near . 0.2 for a wide range of crossflow Mach numbers. This compares well with the two-dimensional value at subcritical crossflow Reynolds number. It is known however. (8) that for cylinders, S varies with crossflow Reynolds number and increases to values in the range 0.3 to 0.5 at supercritical R_{ec} . This has a direct effect on vortex spacing, both longitudinal and lateral. For bodies alone then, S = 0.2 is used for subcritical R_{ec} . It has been found that a value of S = 0.35 gives the best results for supercritical R_{e_c} . For bodies with tails, the rate of vortex formation is influenced by the presence of the tails. Experimental evidence indicates that the effect is to reduce the rate of formation to that defined by S = 0.2 regardless of whether the crossflow Reynolds number is sub- or supercritical. Accordingly, for bodies with tails, S = 0.2 is used throughout.

Using the above empirical and theoretical inputs, a model can be constructed of the asymmetric wake produced by a slender missile configuration at high angles of attack. This model includes the number and locations of vortices in the wake and their strengths, suitably scaled for Mach number and Reynolds number effects. Both growing and shed vortices are included in the model. Having constructed a model of the wake, the next step is to consider its effect on the missile configuration.

4.0 FORCE AND MOMENT COMPUTATIONAL TECHNIQUES

Having established a technique to model the wake produced by a slender missile configuration at high angles of attack, the next step is to calculate the forces and moments induced on the configuration by the wake. This section presents a computational proclure to do this for bodies alone and then for bodies with tails. In either case, the procedure calls for the calculation of incremental effects produced on various configuration segments and then integration of these effects to determine the forces and moments induced by the wake.

This computational procedure was designed with the intent that it not be overly complicated. With this in mind, the following basic assumption was made concerning the location within the body of the image vortices required to preserve the velocity tangency condition on the surface of the body at each axial station. These image vortices are located in the body on a plane perpendicular to the vortex core; however, this raises a problem because of the inclination of the vortex cores relative to the body axis. A cross-section normal to the street cores shows an elliptical body section, inside which the location of image vortices is not simply accomplished. In keeping with the simple nature of this model it was decided that, if possible, image vortices should be located by means of the circle theorem. (14) This was accomplished by resolving the vortex circulation vectors normal and parallel to the body axis. By ignoring the former as having no relevance in the two-dimensional section model, the latter components plus their images could then be used to determine forces and moments. The use of images was not necessary for body quantities, but was, however, mandatory for tailed regions of the missiles. These points are discussed below.

Body Forces and Moments

The calculation of body forces and moments begins with the determination of the incremental force on each body segment. In order to calculate this force, the local net circulation of all the vortices in the wake must be known. Further, these vortices must have their circulation vectors resolved parallel to the body as described above. At any axial station from the nose, there are usually several wake vortices of strength $\Gamma_{\rm g}$ and two growing vortices, one on the left side, having strength $\Gamma_{\rm L}({\bf x})$ and another on the right, of strength $\Gamma_{\rm R}({\bf x})$. Since g is the axial distance over which a vortex grows to full strength then ${\bf x}_{\rm R} = {\bf x}_{\rm L} + {\bf g}/2$ assuming $\Gamma_{\rm R} > \Gamma_{\rm L}$. To resolve the strengths parallel to the body axis, the angle σ for growing and ξ for street vortices were used respectively. Side force on unit length of the body was calculated using the Kutta-Joukowski expression.

$$\delta Y = \rho V \sin \alpha \left[\left\{ \Gamma_{R}(x) - \Gamma_{L}(x) \right\} \cos \sigma + \left\{ \sum_{i=1}^{m} \frac{\overline{R} - r_{i}}{\overline{R}} \right\} \Gamma_{R_{i}} - \sum_{i=1}^{m+1} \frac{\overline{R} - r_{i}}{\overline{R}} \right\} \Gamma_{R_{L_{i}}} \cos \xi \right]$$

Where it has been assumed, for illustration, that there are (m+1) fully developed vortices on the left side of the body and m on the right. The term $(\overline{R}-r_1)/\overline{R}$ is an empirical factor accounting for the attenuation of fully developed vortex effects on the body as their distances from it increases. r_1 is the actual distance of the vortex from the body and \overline{R} is an arbitrary distance at which vortex effect is assumed to have attenuated to zero. The smallest value of r_1 is defined by the Poppl/von Karman intersection point. This formulation was an attempt to model the expected vortex attenuation effect empirically. As will be shown later, it was found that the best representation of forces and moments was obtained when the street vortex strength was allowed to attenuate to zero immediately after shedding.

Total side force Y and yawing moment YM are calculated by numerically integrating along the body length. At this stage in the computerized version of the procedure, an option is provided allowing the user to calculate the effect of varying nose fineness and bluntness ratios. This option uses the data of References 3 and 19 to scale the total body side force and yawing moment for various nose fineness and bluntness ratios. The calculation of individual side forces and yawing moments outlined above, employs the flowfield model developed using the empirical data from Reference 2 to determine street vortex strength and vortex separation points. These empirical inputs were derived from wind tunnel data for a configuration having a 3.798 fineness ratio conic nose. The data of Reference 3, obtained from tests of configurations with noses of fineness ratios of 2, 3 and 4, show that the maximum absolute value of side force, $\left|\text{CY}\right|_{\text{MAY}}$, generally tended to increase with increased fineness ratio for noses with little or no bluntness (see Figure 9). To account for this effect, the data of Figure 9 were used to produce scale factors by which the basic output, based on a 3.798 fineness ratio nose, could be scaled.

The data of Reference 3 also indicated that increases in nose bluntness generally tended to reduce the maximum value of side force. Figure 10 shows the effects of blunting a fineness ratio 4.0 nose. Data were also available for fineness ratio 2.0 and 3.0 nose configurations with bluntnesses of 0, 5, 10, 20 and 50 percent. These data were used to produce scale factors by which the values of side force, already corrected for fineness ratio, could be scaled.

Schlieren photographs in Reference 3 indicate that variations in fineness ratio impact the location at which vortices are shed and that variations in

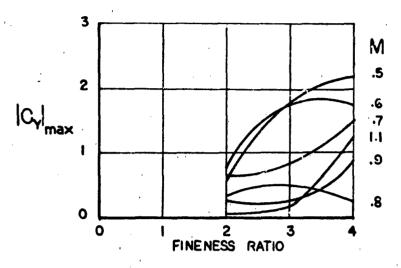


FIGURE 9 FINENESS RATIO EFFECTS

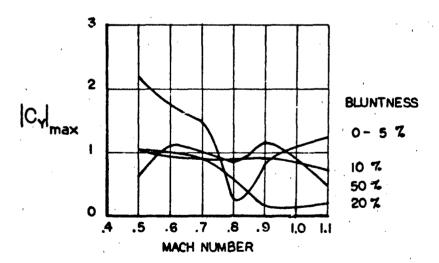


FIGURE 10 BLUNTNESS RATIO EFFECTS

fineness ratio impact the location at which vortices are shed and that variations in nose bluntness delay vortex separation. This is to say that variations in nose geometry influence the structure of the asymmetric wake. Rather than attempting to modify the flowfield model presented in Section 3.0, the scaling technique outlined above was employed in keeping with the simplified nature of the model.

Caution is advised when employing the above scaling technique for nose fineness and bluntness ratio variations. The warning is necessary because the data 3,19 used to derive the scaling factors were mean values and data showing considerable scatter. It is also possible that an independent test of these same configurations could produce considerably different data due to the dynamic nature of the vortex shedding phenomenon.

Tail Forces and Moments

Induced side forces, yawing moments and rolling moments due to the presence of tails can arise even when no asymmetry exists in the wake vortex pattern. This is because of varying net angles of attack of the various tails when the missile is rolled at arbitrary angles. Hence, in order to be certain that experimental data indicate the presence of vortex asymmetry, it is necessary to be selective in choosing missile roll attitudes. For a cruciform missile, roll angles of 0 "plus" and 45 degrees "cross" are the only attitudes where, in the absence of wake asymmetry, zero side forces, rolling moments and yawing moments occur (assuming, of course, no tail deflections). The present model has been compared against experimental data from cruciform missiles and hence the above two roll angles will be referred to exclusively.

The procedure for calculating induced tail forces will be described for a vertical lee-side tail such as could be used on a cruciform missile in "plus" attitude. The major elements of the treatment are most expeditiously described for this case, although the complete procedure will handle tails

at any roll angle so that the program can treat bodies at arbitrary roll or whose tails number other than four.

The first step in the process is to determine, for each vortex, the sidewash velocity induced normal to the tail leading edge at each spanwise station. Since the effects of image vortices must be considered and it is preferred that the circle theorem be used, the wake vortex circulation vector is resolved parallel to the body exis as before. In this case, however, instead of simply resolving Γ_8 through some angle analogous to ξ as was done for the body above, a new strength is defined which will produce the same values of sidewash velocity as did the original vortex. A single vortex in the wake plus its images will induce some distribution of sidewash velocity v along the tail leading edge. The average value of this sidewash is

$$\frac{1}{p}$$
 \int_{a}^{p} vdz

If now the average sidewash is divided by the axial velocity Vcosa, the average angle of attack induced on the tail is obtained. Using the result from slender body theory, that for low aspect ratio tails typical of missile configurations the slope of normal force coefficient is given by #AR/2, the normal force coefficient induced on the tail due to the ith vortex may be expressed formally as

$$C_{N_i} = \frac{\pi AR AT}{2p V \cos \alpha A_R} \int_{A}^{p} v_i dz$$
 (3)

In order to determine rolling moment induced on the missile due to the vertical tail, the resultant normal force is assumed to acr at the centroid of the sidewash velocity distribution or, for the ith vortex

$$c_{i_1} - c_{N_i} \left\{ a + \int_0^p v_i z dz / \int_0^p v_i dz \right\} \frac{A_T}{A_B}$$
 (4)

The total induced forces and moments are obtained by summing the effects of all vortices in the wake.

Yawing moment induced by the tail is calculated by assuming that the resultant loading is located at the mid-point of the leading edge.

The above procedure has been generalized to handle tails at any roll angle. In this way, the contributions of all tails to side forces and yawing and rolling moments may be determined.

Since arbitrary roll angles can be considered, this raises potential problems when a vortex core intersects the leading edge. For potential vortices of the kind used here, flow velocities become extremely high near the core, resulting in unrealistically high induced sidewash angles. This problem was circumvented by introducing into each vortex a solid core of radius 0.25 body radius. (18)

When the tail intersects this core, calculations are discontinued. If the core passes over a tail while angle of attack is increasing, the forces and moments are faired across the gap within which calculations are not performed. This procedure has proved quite satisfactory in practice.

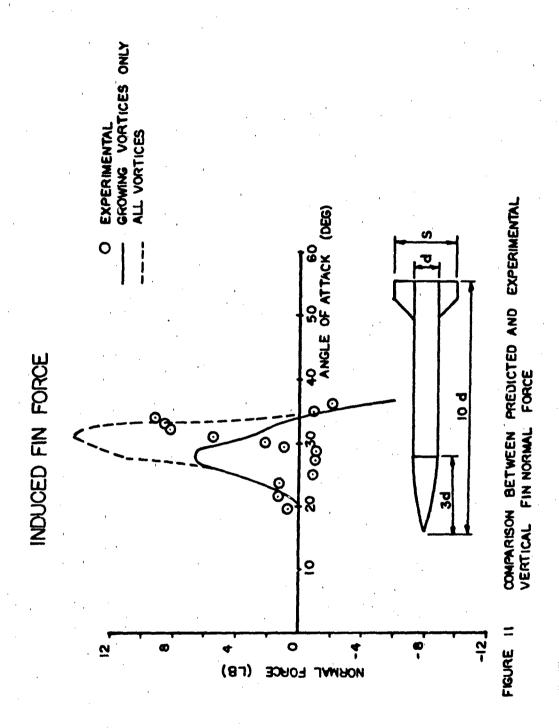
Instead of the slender body theory approach to tail force, strip theory might have been employed. It was felt, however, that the former was more appropriate for the low aspect ratio tails for which the program would probably be used. The program is flexible enough, however, that strip theory could be easily introduced if it were considered necessary.

5.0 COMPARISONS BETWEEN COMPUTED AND EXPERIMENTAL RESULTS

At this stage then, the effects of the wake vortices on bodies and tails are calculable. Comparisons will now be presented between predicted and experimental forces and moments to illustrate the performance of this engineering model. Bodies alone and with cruciform tails will be considered. The effect of varying the number of vortices considered will be shown.

Program predictions have been compared against various experimental data generated on a selection of the Martin Marietta Aerodynamic Research models. (16)
The basic model used for high angle data generation was a 10 caliber tangent ogive/cylinder. This body was tested alone and with several sets of cruciform tails affixed. Each tail was individually instrumented so that program predictions of vertical tail forces and moments could be checked for "plus" attitudes. For tails other than vertical, the program would predict only the incremental force generated on them by the asymmetric wake. Freestream effects were not taken into account, and hence forces for non-vertical tails will not be discussed. However, since the differences between non-vertical tails due to asymmetric effects were presumed to be valid for "plus" and "cross" attitudes, the program was used to predict rolling moments for these attitudes.

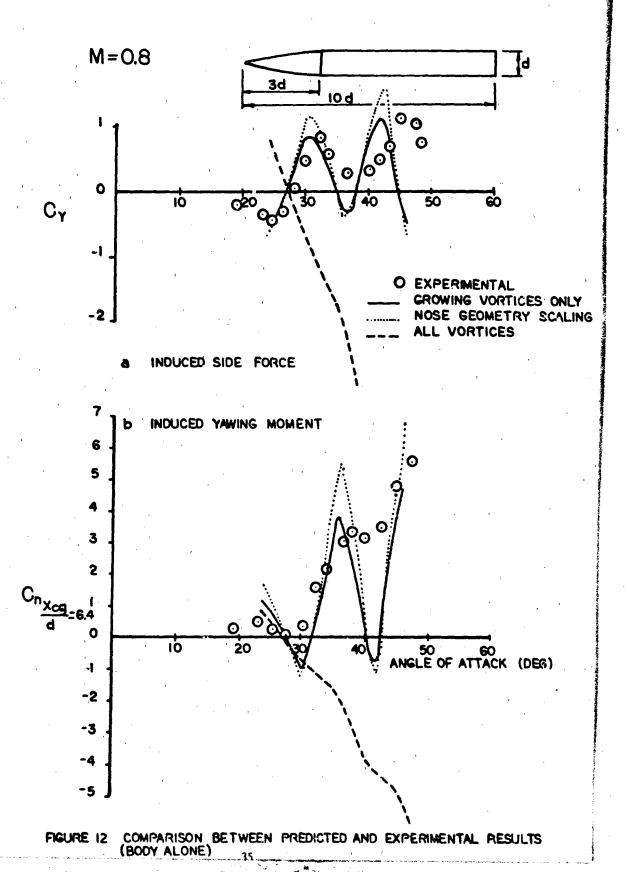
The first comparison is shown in Figure 11. Here, program predictions of normal force on a vertical lee side tail fixed to the body are compared against experimental data. Also shown is the effect of considering all of the vortices in the wake and of using only those vortices closest to the body, i.e., the growing vortices. It will be seen that the magnitude of tail force is predicted within a few percent using only the growing vortices, while use of all vortices produces a significant discrepancy. The angle at which asymmetry begins is matched only fairly, but the angle at which the appearance of a new wake vortex drives the tail force in the opposite

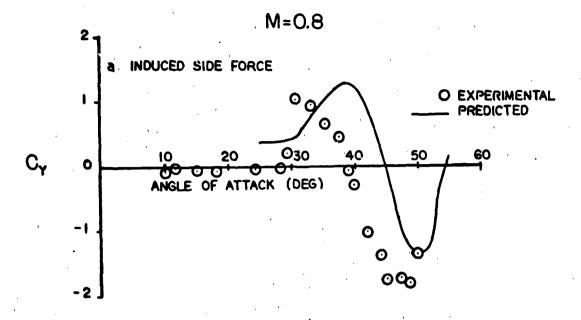


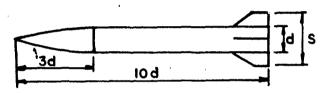
direction is matched within a few degrees. From this evidence, it is concluded that the growing vortices tend to dominate the tail acrodynamic characteristics. The second comparison is shown in Figures 12a and b. Here, predictions of isolated body side force and yawing moments are compared against test data. Again, the effects of considering all of the wake vortices separately from the growing vortices are considered. To make the distinction clearer, no attenuation of non-growing vortex effects has been included. It will be seen that use of all the vortices produces divergent results which have none of the oscillatory character typical of asymmetric effects and evidenced by the dats. This is because the net wake circulation remains unchanged in sign, regardless of the number of vortices present. Use of the growing vortices only, on the other hand, yields quite good matching of force and moment magnitudes, as well as angles of onset and new vortex appearance, at least until several vortices are present. While matching is not exact at the higher angles it is clear that use of the program will produce satisfactory preliminary design level estimates for isolated bodies.

Lastly, comparisons are shown between predictions and data for the 10 caliber body with a variety of tails. Based on the results for tails and bodies, these comparisons contain the effects of growing vortices only. Pigures 13 a, b, and c show side force, yawing moment and rolling moment comparisons respectively. Prediction accuracy is generally satisfactory. In most cases the magnitudes of the quantities are predicted quite closely. On the other hand, the onset of asymmetry and the appearance of new vortices are not always so accurately reproduced.

The results of Figures 11-13 indicate that the vortices growing in the vicinity of the body dominate the induced effects. This appears intuitively correct, particularly in the context of the two-dimensional analogy. There, the vortices closest to the body would be expected to produce the pressure







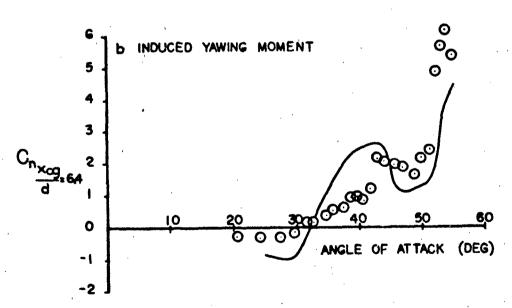


FIGURE 13 COMPARISON BETWEEN PREDICTED AND EXPERIMENTAL RESULTS (BODY+TAIL)

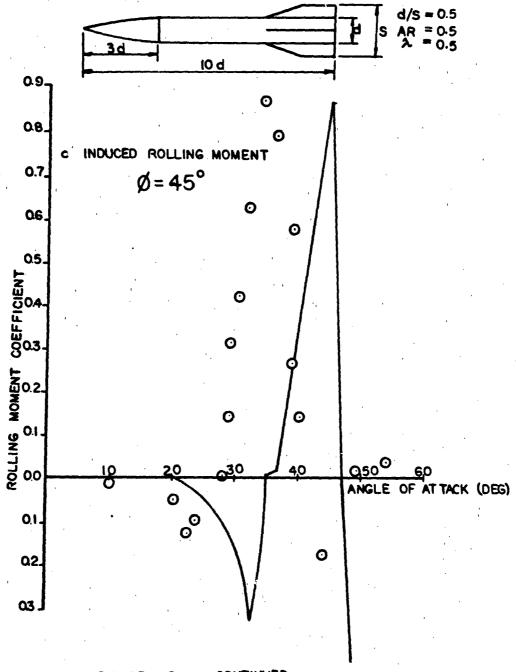


FIGURE 13 CONTINUED

and velocity distributions which generate the forces and moments, with
the remainder of the vortices having little effect as they pass downstream.

It is not unexpected then, that the three-dimensional case should give
similar results. However, although the street vortices have been shown to have
relatively little impact, the experimental information on their strengths and
shedding frequencies remains of central importance since it defines the
bounds of growing vortex strength and shedding frequency.

In general, the model performs quite reasonably. In view of the changes in force and moment data regnitudes and signs which can be obtained by rotation of test models, (1, 3,4) some degree of fortuitousness might be assigned to the results shown. On the other hand, it is unlikely that any measured forces and moments will be significantly greater than those calculated since the model contains all the essential elements of the vortex flowfield, both in magnitude and locations. In addition, it is felt that the means of calculating flow field effects are adequately founded in theory.

6.0 PROGRAM USERS MANUAL

6.1 Input and Output Formats

Input Format:
The input requirements for this program are relatively simple. The
input can be separated into 9 basic groups. The following gives information
concerning each grouping.

Group I - Flow field data

- a. Format: 4F10.0
- b. Variables:

VINF - Free stream velocity in ft/sec

FSMN - Free stream Mach number

RHOINF - Free stream density in $\frac{1b \sec^2}{ft^4}$

ANU - Kinematic viscosity in ft²/sec

Group II - Body Data

- a. Format: 6F10.0, 2I3
- b. Variables:

D - Maximum body cross sectional diameter in ft.

SREF - Body reference area in ft²

NOSEL - Nose length in ft.

BODYL - Body length in ft.

XMC - Moment reference measured from the nose in ft. (absolute value)

DELTA - Nose half angle in deg. Delta = tan^{-1} (body radius) nose length)

NS - Number of segments into which the finless portion

of the body is to be divided. (Maximum of 100 segments)

IDCONF - Configuration Type (0 = Body, 1 = Body + Tail)

Group III - Fin Data (Input only if IDCONF = 1)

- a. Format: (7F10.0)
- b. Variables:

- XF Axial distance in feet from nose to physical fin root chord leading edge. Measured negative from nose aft. (See Figure 14)
- YF Distance in yaw plane from body centerline to fin root chord leading edge. Measured in feet. (See Figure 14)
- ZF Distance in pitch plane from body centerline to fin root chord leading edge. Measured in feet. (See Figure 14)
- XFMAX Axial distance in feet from nose to fin tip chord leading edge. Measured negative from nose aft. (See Figure 14)
- YFMAX Distance in yaw plane from body centerline to fin tip chord leading edge. Measured in feet. (See Figure 14)
- ZFMAX Distance in pitch plane from body centerline to fin tip chord leading edge. Measured in feet. (See Figure 14)

SREFT - Tail single panel reference area in ft. 2

The above measurements apply to a single lee-side fin in the pitch plane of a non-rolled missile.

Group IV - Indicators

- a. Format: (313)
 - Variables
 - NAOA Number of angles of attack to be considered. As mary as

 30 angles of attack may be entered per run.
 - NTYPE Nose type indicator

1

NTYPE Nose Shape

Cone

2 Tangent Ogive

NLAM - Number of roll angles to be considered. As many as 30 roll angles may be entered per run.

Group V - Angles of Attack

- a. Format: (8F10.0)
- b. Variables:

AOAD - Angles of attack in degrees (See Figure 14)

Group VI - Roll Angles

- a. Format: (8F10.0)
- b. Variables:

RA* = Roll angles in degrees (See Figure 14)

*Locates fin positions relative to leeside vertical, RA = 0.0

Group VII - Radial Vortex Limit

- a. Format: (F10.0)
- b. Variables:

GAMLIM - Radius at which the influence of a vortex on the body goes to zero. (diameters)

Group VIII - Nose Fineness and Bluntness Ratio Option

- a. Format: (I1.F10.0)
- b. Variables

IOPT1 - Option indicator

(0 = Do not use option, 1 = use option)

BRN - Bluntness ratio in percent (Nose tip radius X 100)

Group IX: Run Configuration Indicator

- a. Format: (I1)
- b. Variables:

Output Format:

Output format will be determined by the nature of the configuration being analyzed. Output for isolated bodies consist of angles of attack, side force coefficients (CY) and vawing moment coefficients (CETAMC) about the moment center input by the user. If the fineness and bluntness ratio scaling option is selected, output will be scaled and repeated. Output for body plus tail configurations consist of angles of attack, induced side force coefficient (CY), yaving moment coefficient (CETAMC) about the user input moment reference center and rolling moments. Additionally, for a fin located in the lesside vertical plane (RA = 0.0), the force normal to the fin is also printed out.

FIGURE 14 SIGN CONVENTION

6.2 Program Flow Charts

Two program flow charts are presented. The first (Chart 1) is a generalized flow chart designed to provide the user a basic map of program functions. The second flow chart (Chart ?) is designed to give the user requiring a working knowledge of program functions a more detailed breakdown of program logic.

Descriptive statements are also contained in the program listing in order to facilitate tracing the steps through the program.

Chart 1. Top Level Program Plow Chart

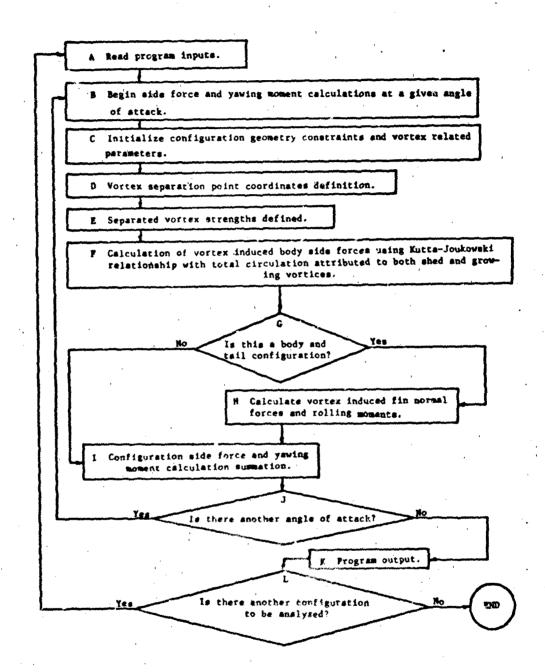


Chart 2. Detailed Program Flow Chart

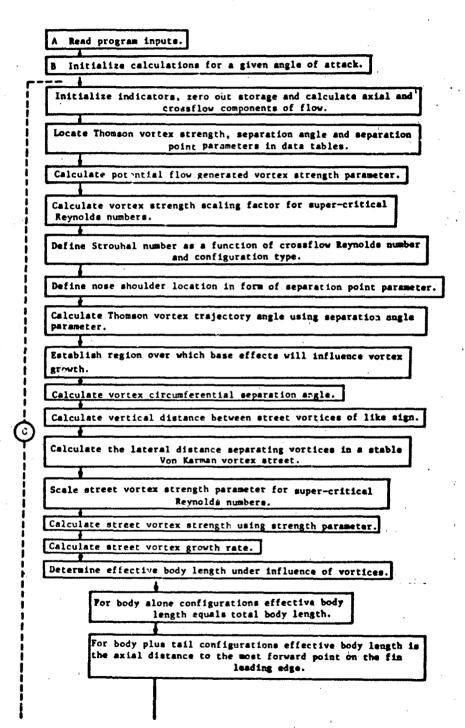
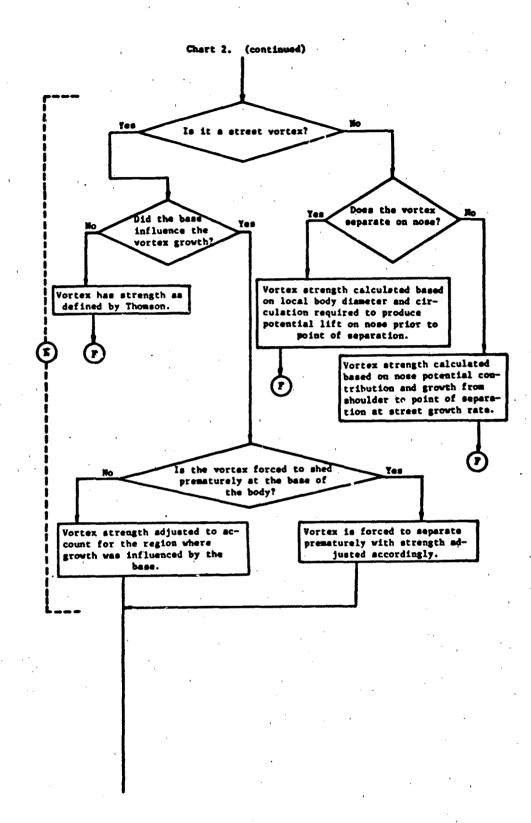
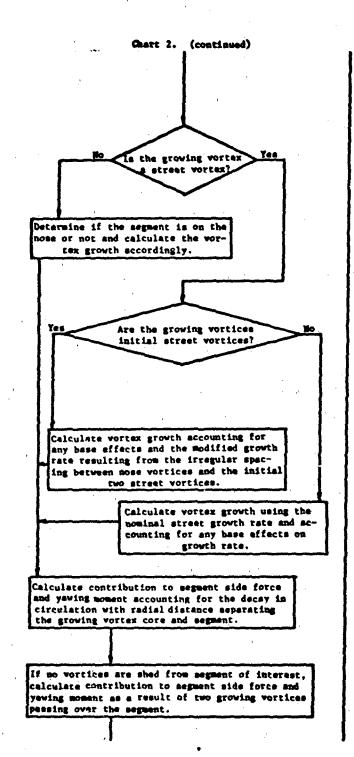


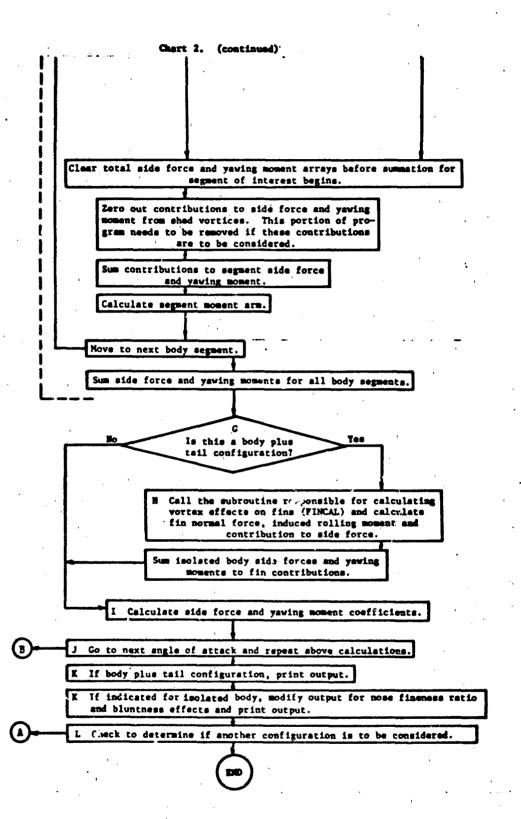
Chart 2. (continued) Divide the effective body length into the specified number of segments or computation intervals. If the effective body length is sufficiently long to shed more vortices then the Thomson data tables indicate, add additional street vortices at regularly spaced street separation intervals. Using vortex separation point parameters, calculate axial separation points. Examine each body segment to determine if Thomson axial separation points fall within the segment. After locating Thomson's separation within a segment, determing if separation point is on the nose or cylindrical portion of body. Using local body diameter, calculate coordinates of point where Thomson's vortex trajectory penetrates surface. Redefine vortex axial vortex separation points as those points where

Thomson's vortex trajectories penetrate the body surface.



separating the growing vortex core and segment.





6.3 Program Listing

```
THIS PAGE IS BEST QUALITY PRACTICABLE
                            JROM COPY PURMISHED TO DDC
                                                                       0000010
  REAL LAMONUSE OF AMD
                                                                       0000020
  DIMENSION GSEOP(20) . SEP(20) . AUAP(34) . APAR(30) . GA454(20)
  DIMENSION GAMPC(20) + GANT(100) + SF(100) + CY(100)
                                                                       0000030
                                                                       00000040
  DIMENSION YMOM(100) . CETA (100) . GSE >T(20) . GSEPY(20) . GSEPZ(20)
                                                                       00000050
  DIMENSION ASSEP(20) + 34(30)
  DIMENSION FMG>C(20)+3PSV(20)+FMGOSV(20)+GMUTS(20)
                                                                       00000060
  05) UEDF1. (05) UED . (05) 7. NOT 10. (20) . FHED . (20) . FHED . (20)
                                                                       00000070
                                                                       00000080
  DIMENSION CETAMO(100)
                                                                       0n00n090
  DIMENSION FAT (100) + FNFQ (30)
  DIMENSION SEPC (20) . SEPOV (20) . SEAUTS (20) . SERVAS (20) . CEGBJ(20)
                                                                       00000100
                                                                       00000110
  DIMENSION THACHC(17) . TALPHA(6) . TRAMP(17.6)
                                                                       00000120
  DIMENSION ISKIP (30) + SROLM (30)
                                                                       00000130
  DIMENSION TXI(17) + T36 EP(17+7)
  DATA TGAHA/ 2.8 + 2.8 , 2.8 +2.8 +2.8 , 2.41 . 2.84 + 2.9 + 3.0 , 3.11
                                                                       00000140
 2 , 3.28 , 3.41 , 3.5 , 3.5 , 4.0 , 4.19 , 4.03 , 3.0 , 2.48 , 2.490n00n150
   . 2.48 . 2.49 . 2.49 . 2.5 . 2.55 . 2.45 . 2.78 . 2.92 . 3.09
                                                                       00000160
    3.28 + 3.49 , 3.58 , 3.84 + 3.72 + 3.5 + 2.1 + 2.1 + 2.1 + 2.1 0000170
   . 2.11 , 2.13 . 2.15 . 2.26 , 2.38 . 2.51 . 2.68 , 2.85 . 3.06 , 0n000180
                                                                       00000190
     3.27 , 3.42 , 3.35 , 3.12 , 1.4 , 1.4 , 1.6 , 1.41 + 1.62 +
     1.65 + 1.69 + 1.77 + 1.85 + 2.0 + 2.12 + 2.3 + 2.5 + 2.7 +
                                                                       00000200
     2.88 , 2.79 , 2.5 , 1.1 , 1.1 , 1.1 , 1.1 , 1.1 , 1.13 , 1.17 0n000210
                                                                       00000220
    1.2 . 1.29 . 1.37 . 1.5 . 1.64 . 1.81 . 2.0 . 2.12 . 2.09 .
     1.93,.61 , .61 , .51 , .62 , .63 , .64 , .67 , .7 , .75 , .81
                                                                       00000230
  , 9 , .99 , 1.1 , 1.51 , 1.31 , 1.29 ,1.18 /
                                                                       00000240
  DATA TMACHC/ n.g .U.U5 .U.L . U.15 . 0.2 . n.25 . 0.30 . 0.35 .
                                                                       00000250
                n.4 . 7.44 . U.5 . n.54 . n.k . 0.65 . 0.7 . n.75 .
                                                                       00000260
                                                                       00000270
                ".A /
                                                                       00000280
  DATA TALPHA/ n.n + 20.0 + 30.0 + 40.0 + 50.0 + 50.0 /
  DATA TGSEP/ .12 + .16 + .19 + .23 + .26 + .29 + .32 + .35 + .39 + 0n000290
               .42. .45 . .47 . .50 . .52 . .53 . .56 . .58 . .23 . Onnon30n
               . 27 , . 3 , . 34 , . 30 , . 42 , . 47 , . 5 , . 53 , . 57 , 00000310
                                                  , .72 , .53 , .57 , 0n00n32n
               .39 . .52 , .64 , .67 , .63 , .7
                                                  . . 93 . . 97 . 1 . 0
                                                                     . 00000330
               .71 . .76 . .6 . .93 . .97 . .9
              1.02 .1.05 .1.00 .1.1 .1.12 .1.13 .1.18 .1.23 .1.27 . 0000340
                                                              .1.52 , 0n00n350
              1.32 ,1.35 ,1.38 ,1.42 ,1.44 ,1.46 ,1.48 ,1.5
              1.53 .1.56 .1.57 .1.54 .1.6 .1.68 .1.73 .1.78 .1.82 .
                                                                       00000360
              1.96 +1.44 +1.92 +1.94 +1.97 +1.98 +2.n +2.92 +2.04
                                                                       00000370
              . 66.5. 56.5. AS.S. ES.C. AI.C. 1.5. 40.5. Pr.S. 40.5.
                                                                       00000380
                  ,2.43 ,2.45 ,2.47 ,2.4A ,2.5 ,2.52 ,2.53 ,2.56 .
                                                                       00000390
              2.4
              2.58 .2.59 .2.5 .2.68 .2.73 .2.78 .2.82 .2.36 .2.9
                                                                       00000400
              1.7. 90.8. 80.8. 60.5. 50.5. 10.8. 84.5. 64.5. 56.5.
                                                                       00000410
                                                                        00000420
              3.11 +3.12 /
               .745, .775, .735, .735, .71 , .61 , .657 , .793, 00000430
              .alo. .312. .Hi2. .alo. .Alp. .al . .a0c. .B
  PRITAMARA FIROV BELIABILINI ONA ATAC TURNI CAR
  READ FREE STHEAT CONDITIONS
                                                                        00000510
41 HEAD (5.1) VINF. FRM V. 7-1DENF. AND
                                                                        01000511
1 FORWAT(4F10.0)
                                                                        00000512
2 FORMAT (4F10.0.213)
                                                                        00000513
3 FORMAT(313)
                                                                        00000514
 4 FOR 4AT([1.F10.0)
  READ CONFIGURATION INFORMATION
                                                                        00000620
   READ(5.2) TOSREFONDSELONDUYLOFALONELTAONSOTOCONF
                                                                        00000630
   IFIIDCONF.EJ. n) gu To 20
   READ FIN DATA FOR BOY PLUS TALL CONFTG IRATIONS
                                                                        04600680
   READ(5.1) XF. YE. ZF. XFM4A. YFMAX. ZFMAX. SREFT
```

MAIN

		•	0-00-700
	20	DELTAH=06174/57.29577	00000700
•	•• ••	READ NUMBER OF ANGLES OF ATTACK. NOCE TYPE AND NUMBER OF ROIL	
3		ANG_ES	0-00-760
,		READ (5+3) NADA . NTYPE+N_RY	00000760
C		READ ANGLES OF ATTACK	
•		REA)(5+1) (A)A)(T)+1=1+ NAOA)	00000820
_		REA) ROLL ANGES	
C		REA)(5+1) (HA(T)+1=1+N-MM)	00000860
		READ RATE TIME OF VORTER INFINENCE	
C,		READ(5+1)GAMLIM	00000910
_		READ NOSE FINENESS AND BLUNTNESS OPTION DATA	
C		READ (5+4) TOPT + HRU	00000917
		STARE ANGLE OF ATTWCK LOUP	_
C,			00000920
		DO 51 [=1.NAUA	00000930
		77ces.12/(1)CAMA (1)FAMA	0000940
	51	CONTINUE	00000950
		DO 52 1=1+N404	01001961
		ISKIP(I)=n	00000970
		IST THE J	07000980
		NORA=1	01001990
		LAMERA (VU 7A)	00001000
		LAM J=LAM	00001010
		LAM=LAM/57.29577	00001020
			00001030
		XED==1-+(1/2-)+S[4(-0/4)	00001040
		- TPN	00001050
		ZFR=(D/2+)+CDS(LA4)	00001060
	51	DU +1+ K=1+A2	00001070
		ZFR=(D/2.) *COR(LAM) DO 414 K=1.NS SF(<)=0.0 COMTINUE DO 415 J=1.20 AGS=P(J)=0.7 COMTINUE CY(I)=0.0 SRO_M(I)=0.0 CETA(I)=0.0 CETAMC(I)=0.0 CROSS FLOW VE_OCITY ASO MACH NUMBER	00001080
	414	CONLINAE	00001090
		00 412 7±1+50	00001100
		- AGSEP (J) =0+7 등 등 등 등 등 등 등 등 등 등 등 등 등 등 등 등 등 등 등	00001110
	415	CONLINGE	00001120
		CY(1)=0.0	00001130
		SRO_M(I) =∩•U	01001140
		CETA(I)=U.U	00001150
		CETAMC(T)=0.0	
C		CROSS FLOW VE OCITY AND MACH NUMBER	01001160
		ACMATAL ADIATA INSTITUT	00001170
		CFM N=FSMN+SIN (A)A+(T))	
C		AXIAL VELICITY AND MACH NUMBER	34001180
-		AMAA=FSMN+COS(ANAR(II))	00001190
•		VINFA=VINF#205(A0A3(1))	00011500
	•	AOA=MOAD(T)	00001510
			A11A - 1 C - A
C-		GO TO NEXT ANGLE OF ATTACK IF CHORS FLOW MACH DATA PROCEDED	00001220
_		Dn 30 II=1+17	0001230
		1101=11+1	2001240
		terrio: G1.17.G0 f) 41	AUAAIEAU
C		THE PROPERTY OF THE PROPERTY O	00001250
		IF (CFMN. GE. IMACHC (II) . AND. LEMN. IF. THACHC (TIP1) 130 TO 32	0001250
	30	CONTINUE	0001270
	32	2 DO 34 K=1.6	
	74	KDI=K+1	0,001280
		**************************************	00001290
		IF (ADA.GE, TALDHA (K) . A NI) . ADA.LE. TA_P 46 (KP)) TO TO	00001300
	24	And Table	00001310
^		CONTINUE FOR THOUSON VUNTER STREIGTH PARAMETER AND THOUSON	
C		· 基理专业TT 单位中下版(T. TT - T. TT - T.	

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MATN

C		SEPARATION ANGLE PARAMETER	
	35	A=(TMACHC(II)=CFMN)/([14CHC(II)=TMACHC(TTH1))	00001320
	-	TGK=TGAMP(11+4)-(A*([344P(11+K)-T344P(11P1+K)))	00001330
		TGKP1=[GAMP(IT+KP1)-(A+(T3A4P(IT+KP1)-T3A4P(IIP1+KP1)))	_
			00001340
		B=(TALPHA(K)=AOA)/(TA_PHA(K)=TALPHA(KP1))	01001350
		GAMP#TGK-(H*(TGK-TGKPI))	0n00136n
		XI=TXI(II)-(A+(TXI(II)-TXI(II-l)))	0n001370
		DO 52 JJ=1+7	00001380
C		INTERPOLATE FOR THOMSOM SEPARATION DOTAL DARAMETER	
_	1	GSEPP(JJ)=[3S=P(II.JJ)-(A+(TGSEP(TI.JJ)-TGSEP(IIP).JJ))	00001390
	43		
	DC		00001400
	'	60 TU 36	0,001410
	31	GAMP#().i)	0n00142n
C.		CROSS FLUX REYNOLDS NUMBER	
	36	RNC=VC*O*A_	0n001430
	. •	PI=3.1+159	00001440
C			0441440
•		VORTEX STRENGTH PARAMEREN DASED ON MICH POTENTIAL LIFT	
_		GAMPR=(P1/8.)+(P.*C)5(AUAR(1))+(STY(ANAR(1))**2.))	0n001450
C		VORTEX STALIGTH SCALLING FACTOR	•
		AF(FSMN.LE.1.n)PAFID=.25+(.1967+C=4V)+(1.7556*CFMN+.2.)	0n001460
		IF(F5MN.GT.1.0.4N).CF4W.LT.0.15)PATTO=0.2E+(.1957*CEMN).	0n001470
		1 (1.7556@CFMVP#2.)	00001480
		IF (FSMN. G1.1 AND. CF4 V. GE 15. AND. CFMV. (E. 0.55) 04+10=	00001490
		10.25=(0.35754*CFM+)+(7.3598#CFM+##2.)=(0.154*CFW+#4.)	
			00001500
_		IF (FSMN.GT.L.n.aN). CF 4N.GT.00-551 PATT/1=1.0	0~00151n
Ç		STROUHAL NU 4HER	
		S=.?	0n001520
		IF(RNC.GT.1.E+05)5=1.35	00001530
		IF(IDCONF.E1.1) <=.?	00001540
C		SHOULDER LUCATION IN TERMS OF SEPARATION BOTHT PARAMETER	
•		SNOSEL=NUSE_FTAN(4714(1)) #5/U	0.001550
C	٠		01001550
C		THOUSON VORTEX SEPARATION ANGLE	
_		E=ATAN(YIPTAN(ADAR(I)))	00001560
C		LENGTH OF HOUY INFLUENCED BY BASE ESFECTS	
		ERASE=U/(/, PTaN(E))	00001570
		AXLEMHO YYL-EHASF	0001580
		AGMENT=] -54TA4(DE_TA4)/TA4(ADAH(T))	00001590
		IF(ASME)(F.G.).n)37 TO 52	00001600
C		CIRCUMFERENTIAL SEPARATION ANGLE	411441940
•		THETAL=ASIN(1.5+TAN(DELTAP)/TAN(ADAD(1)))	0.001110
_			90001610
C		VERTICAL DISTANCE BEHAVEN VONTICES OF LIKE SIGN	
_		DL*D*TI/S	0001620
C		STABLE VORTEX STREET LATERAL SEPARATION INTSTANCE	
		M=,261+1L	00001630
		IF(RNC-LT.1.E+05)30 TO 55	00001640
C		SCALE THOUSON VORTER STRENGTH FOR SHEERCRYTTCAL CROSS F. DW	
Č		REY VOLUS NU 48FRS	
•		3AMP#GA 4P#HATTO	6 - 6 0 4 E 6
_			0n001650
C		THOUSON STREET VURLEN STRENGTH	•
	55	GAMEBAMP#VINF#D#SIN(#JAR(]))	0n001660
		GANTAGA +	00001670
C		AXIAL DISTANCE RETWEEN SEPARATION POINTS FOR STREET MORTICES OF	
C		LIKE SIGN	
-		DG=(GSEPH(7)=35FPP(3))+J/(TAN(Anna(1))+5)	0000.680
		DGA 4#GA 41	00001690
C		STREET VONTEX GROUTH HATE	AUAAIOAA
•		GRATE*UGAM/)G	A . A A . TA .
_			00001700
C		EFFECTIVE HODY LENGTH	

```
00001710
               IF (IDCUME-Elen) XF =-30)YL
                                                                                                                                                                              0001720
              EHODYL = XF
               BOOT SEGMENT ENGTH
                                                                                                                                                                              00001730
               SEG_#AUS (EBODYL)/NS
              DO 500 J=1.20
IF(J.LT.8)GO TO 300
                                                                                                                                                                              00001740
                                                                                                                                                                              00001750
               2-C= 5ML
                                                                                                                                                                              00001.760
              GSE = T(J) = GSEPT(JM2) + ) 3-
                                                                                                                                                                              00001770
                                                                                                                                                                              00001780
              80 TO 600
               VORTEX AXIAL SEPARATION POINTS AS OFFINED BY THOMSON
                                                                                                                                                                              00001790
     300 GSE=1(J)=GSEP=(J)+7/(144(AUAH(I))+5)
                                                                                                                                                                              00001800
     600 CONTINUE
              CALCULATIONS TO DETERMINE COORUTIATES OF ACTUAL SHAFACE SEPARATION
C
C.
               POINTS HISTNS THOMSON DATA. CIRCHMFERENTIAL SEPARATIONANGLES AND
              LOCAL BODY DIAMFTERS
               AXI =U. 0
                                                                                                                                                                              0n00181n
                                                                                                                                                                             00001820
              J= 1.
                                                                                                                                                                             00001830
     603 AXL=AXL + SEG
               AXL 41 = AXL-SEGI
                                                                                                                                                                              00001840
     608 IF(35FPT(J).LE.AS...*N).GSEPT(J).GT.AKLM1)GO TO 502
                                                                                                                                                                             00001850
                                                                                                                                                                             00001860
              60 TU 603
                                                                                                                                                                             00001970
     602 IF (35EPT(1) .GT. HUSF_0 30 10 504
               IF (NI YPE.EQ. 2) Gn 19 505
                                                                                                                                                                             00001880
              CONTU HOSE LOCAL RADIUS CALCULATIONS SIG = ASIM((D/2.)/NDBEL)
C
                                                                                                                                                                             00001890
                                                                                                                                                                             00001900
              RAXLEAXLETAY(SIG)
                                                                                                                                                                             00001910
               RAK_MI=AXLMI=TAN(513)
               YZP MERAKLOSI V (THETAI)
                                                                                                                                                                             00001920
                                                                                                                                                                             00001930
               Y2= 74XL -- 1 + 5 [N (THE [ 1 ] )
                                                                                                                          PRO COUNT PROPERTY PROCESSES OF TO DOO OF THE SESSES OF TH
                                                                                                                                                                             00001940
               Y284=(Y2+Y2P3M)/?.
                                                                                                                                                                             00001950
              REMSEG=#XL-SSFPT(J)
              DELY=REASEGATAN(E)
                                                                                                                                                                             00001960
              STFORAKL
                                                                                                                                                                             00001970
                                                                                                                                                                             0001980
               1F()ELY.LT.Y24A4)31 17 606
              DFL S=Y23A4/TA4(F)
                                                                                                                                                                             00003990
              65f 2(J) =64t21(J) + )E_6
                                                                                                                                                                             0002000
              GSFPY (J) #Y23A7
                                                                                                                                                                             0102000
              (IAPEMI) VAT/KAESYE (U) NEBAI
                                                                                                                                                                             00005050
                                                                                                                                                                             00002030
               1=1-1
              IF (J. 61.20) 30 To 507
                                                                                                                                                                             0405,000
                                                                                                                                                                             0n00205n
              55 10 bad
     696 STEPSSTEPSSEG
                                                                                                                                                                             0002060
              STFPH1=STEP+SEG
                                                                                                                                                                             0002070
              RAX_=STEP+TAN(STG)
                                                                                                                                                                             0002080
              RAX_MISSTEPHIOTAN(SIS)
                                                                                                                                                                            07002090
              YZPRM=HAKL#SIN(THETAI)
                                                                                                                                                                            0002100
              YZ=RAXL #1+SIN(THETAT)
                                                                                                                                                                            61002110
              ASHUMETA FASHOWINS"
                                                                                                                                                                            01002120
              DEL SEYZHAR/TAU(F)
                                                                                                                                                                            01002130
              65E3(J) #65E37(J)+)E_6
                                                                                                                                                                            09007140
              IF (35FP(J).3T.STEP; 30 TO 506
                                                                                                                                                                             0002150
              GSE 27 ( 1) = Y 2 3 A 3
                                                                                                                                                                             04005160
              (IATINT) / AT/CAESY=(L) 1938
                                                                                                                                                                            00002170
                                                                                                                                                                            0002190
              J=J+L
              IF (J. 81.2") 30 TO 507
                                                                                                                                                                            00002190
              60 TU 603
                                                                                                                                                                            0005500
```

	TANSENT USIVE LOCAL PADIUS CALCULATIONS	
		00002210
605	TORAD=(3/4.)+((NOSE_##2.)/U)	0.005550
	(DAQT-(-5/07))+((-5++(1360-144))-(-5++0AFOT))TFH24_KAR	00005530
	RAX_MI=SURT((TORA)++2.)-((AKLM1-N)SFL)++2))+((D/2.)-TORAD)	
	Y2PRHERAXL#SIV(THETAI)	0.002240
	YZ=RAXLAL+SIN(THETAI)	00002250
	Y284#(Y2PH4+Y2)/2.	00005560
	REMSEG=4X1-3SFPT(J)	0002270
	DEL YRENSEGOTAN(E)	00005580
	STEPAAL	00005580
	IF(DELY.LT.YZRAR)30 TJ 507	0005300
	DEL 38Y2AAR/TAN(F)	04005370
	GSE=(J)=GSE=T(J)+)E_B	00005350
	GZE3Y(J)=YZ3A3	00005330
•	(TATIENT) VATISATIVATIVATIVATIVATIVATIVATIVATIVATIVATIV	0n0C2340
•	J=J+1	0002350
	IF(J-G1,2n)30 To 507	01002360
	60 10 eug	00002370
	STEP#STEP+SEG	00002380
907	5 6-43 C+3 C	00002390
	STERMITSTEP-STGL RAXLESQRI((TORAD**2.)*((STEP-NOSF_0+*2))+((D/2.)-THRAD)	0002400
	(nasc====================================	00002410
	MAX WIRE SERI (LOUR JAMES) = ((2) CEM (# 400 C C) AMS ()	0002420
	YZPRMEHAXL+SIN(THETAI)	00002430
	AS=SVENTOSIN(LMELVI)	0002440
	4584H=(45+45b3H)\5.	00002450
	DEL3#Y2HAP/[AN(F)	0002460
	65E=(J)=65E=T(J)+JE_G	0002470
	IF (3SEP (J) . ST. STEP) 30 TO HUY	0002480
	FAESY=(L)YC328	0002490
	GSE72(J)=YZ3A7/TAT(THETAI)	00002500
	JmJ+l	00002510
	IF(J.6T.20)30 To 507	01002520
	OO TO 608 VORTICES SEPARATE FRUM CYLINURICAL RODY SECTION	
	ASBURE (D/5") & LIM (LHELLAI)	00002530
004	DEFREASHVALVA(E)	00002540
	GSEP(U)=GSEPT(U)+DE_B	0002550
		01002560
	GSEPZ(J)=YZ363/T64(THETAI)	0002570
		01002580
	Jaj+k	0002590
	IF(J+GT.20)30 Tn 507	01002600
	GO TO 518	01002618
. 507	' VCO JNT=3	
	ADJUST VUDITER STRENGTIN ACCOUNTING FOR MORE EFFECTS AND BASE	
•	ADJUST VUSICA STREAM A ACCOUNT TO A	
	INF_UENCE UN GROWTH HATE	
ě	JST JH=0	,
	00 33 J#1+20	0002620
	40. 40. 3.60. 00. 66	06002630
	1F(J.EU.1)G) TO 97	0002640
	IF (485 (GSEP (1)) . GE. 40 SEL) (60 TO 94	00002650
<u>~</u>	7 IF (35EP(J) - 3E . NOSEL) 30 TO 9H	00002660
4	IF(NIYPF.FU.21Gn In 9)	00002670
	SIG#ASIV((U/2.)/NOSEL)	0n002680
	DCS=2.*35FP(J)*TAY(513) .	0.002690
		00002700
	- 60 TO 100 9 TORAD#()/4.)+((NOSE_#*7.)/U)	0000271
. 9	A I (DAMPARINA PLA (ELICAZITE, LATVA)	-

```
RCS=SURT((TORAD##2.)-(A35(USEP())=VOSEL))+#2.)+
                                                                              00002720
                                                                              00002730
    1 ((D/2.) -TORAU)
     DCS=2. *HCS
                                                                              0000740
     VORTER STRENGTH FOR VURITUES SEPARATING ON NOSE SECTION
                                                                              00002750
 100 GAMEGAMPZ#VINF#SIN(ADAD(I))#UCS
     GO TU 95
                                                                              00002760
  98 PGA4=GA4P2+VI4F+SI4(AJHR(I))+D
                                                                              00002770
     DELXI=GSEP (J) -NOSEL
                                                                              00002780
                                                                              00002790
     GAM=PGAM+DELX1#GRATE
     IF (GAM.ST.GAM)) GA 4= GA 41
                                                                              0002800
  96 IF (J.GT.1) GAM==1.8544
                                                                              00002810
                                                                              00002820
     GSEP(J) =-1.0*3SEP(J)
     IF (AHS (GSEP (J)) GT. 4x E) GJ TU 701
                                                                              00002830
                                                                              04AS0000
     GAMSV (J) =GAY
     GO TO 702
                                                                              00002850
     PTREET VORTEX STRENGER WHEN INFINIENCED BY BASE
                                                                              00002860
 701 JH2=J-2
     VORTEX STRENGTH ADJUSTED TO ACCOUNT FIND RASE EFFECTS
     IF (ABS(GSFP(J42)).ST.4(LF)GAMSV(())=0.4490ATF4(ABS(GCEP(J))-ABS(GEE06002870
    19 (342)))
                                                                              04002880
     IF (ABS (GSEP (JW2)).LT. AXLE) GAMSY ( 1) = GRATE G(AXLE GABS (GSEP (JW2)))+
                                                                              00002890
                                                                              00002900
    10.4 #GHATE# (ARS (GSEP (J)) -AXLE)
     IF (SAM.LT.U.U) GAMSV (J) =-GAMSV (J)
                                                                              0n00291n
 702 IF (ABS (SSFP(J)) LE. 435 (EBOUYL) I AO TO 301
                                                                              04002920
     VORTEX STRENGTH CAUCULATIONS FOR VONTICES FORCED TO SEPARATE
     PREMATURELY, BY THE EFFECTIVE BONY LENGTH
     I-C= [ML
                                                                             00002930
     7-FEZME
                                                                             00002940
     DRODY=ARS(EBONYL)
                                                                             00002950
     IF (NCOUTT.EJ. G. ANJ. ARS (35EP (UNIT) . En. AMP (FUNDYL) 160 TO 302
                                                                             06002960
                                                                             00002970
     IF ( VCOU IT. E 1. T) GU TO 302
     NEOJNI = NCOUNT+1
                                                                             00002980
     CALL: XYZ(4+)++HETAI+A35EP(J)+35FP(J)+65FP(J42)+3400+65FPY(J)+65EP06002990
    12(J)+41+4?)
                                                                             00003000
     AGSEP (J) =3SEP (J)
                                                                             00003010
     SEPARATION POINT FIXED AT EFFECTIVE HODY LENGTH
                                                                             0003020
     GSF2(J)=t.40)Y
     IF (AUS (SOEP (JAZ)) . SEGATLE) WAMS / () = 1.4#SPATEP (AHS (GEEP (J)) -
                                                                             00003030
                                                                             00003040
    TARS (GSEP (JMZ) ))
     IF (AUS(GSEP(UV2)).LT.AXLE) WANNY (!) = RRATEO (AKLE-AUS(GSEP(UM2)))+
                                                                             00003050
    10.4*GRATE*(ABR(GSEP(J))-AXLE)
                                                                             00003060
     1F (3A4.LT.U.0) GAMSV (J) =-GAMSV (J)
                                                                             00003070
     GO TO BALL
                                                                             00003080
 302 CALL X17(4.).THEFAI.4352P(U).65FP(U).RSEP(UM2).DHODV.GSEPY()).GEEPO0003090
    12(J) + A1 + 42)
                                                                             00003100
     AGSEP (J) #GSEP (J)
                                                                             00003110
     GSEP(J) = ERODY_
                                                                             00003120
     IF(ABS(GSEP(J4P))).TTLAXLE)UAM5V(I)=1.44TPATF4(ARS(GCEP(J))=
                                                                             01003130
    TARS (USEP (JM2)))
                                                                             00003140
     IE(AUS(GSEP(UvP)).LT.AXLE)DAMSV/})=GPATFO(AXLE-AUG(GSEP(UMP())+
                                                                             0n00315n
    10.4#GRATE#(ABS(GSEP(J))-AALE)
                                                                             00003165
     4F (3A4.LT.0.0) GAMSV(J) =-GAMSV(J)
                                                                             00003170
     L=xAML
                                                                             00003180
     JSTOK=20
. 301 TF (SAM. ST. U. O) GAMESAME
                                                                             0003200
     IF (SAM.LI.U.U) GAM=-1.0+GAMA
                                                                             00007210
     IF (JSTOR.EQ.24) GO TO land
                                          THIS PAGE IS DEST QUALITY PRACTICABLE
  53 CONTINUE
                                                                             00003220
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and the same of the first that the

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AT THIS POINT ALL SHEW VURTICES HAVE THETO CORRECTED STRENGTHS
     AND SEPARATION DOINTS ASSIGNED. REGIN CALCULATIONS TO DETERMINE
     THEIR INFLUENCE ON THE CONFIGURATION OF THTEREST.
1000 JENTEUMAX+1
     CLEAR APRAYS
                                                                            0-003240
     00 510 J=JEND.20
                                                                            0003250
     GSEP(J) =0.0
                                                                            0003260
     BSF = Y (J) = 0 . ()
                                                                            00003270
     GSE=2(J)=0.0
                                                                            085£00n0
 610 CONFINUE
                                       THIS PAGE IS BEST QUALITY PRACTICABLE
                                                                            01003290
     AXL=U.0
                                                                            04003300
     SEG_=AUS(FUDDYL)/YS
                                                                            00003310
     DO 200 4=1+45
                                       TROM JULY PURALSHED TO DOG
                                                                            0003320
     XAPF-1=11 092 00
                                                                            01003330
     GAMPC(II)=0.0
                                                                            0n003340
     SEPC(II) = a.a.
                                                                            00003350
     FMG >C(IT) =0.U
                                                                            00003360
     SP54(II)=0.0
                                                                            01003370
     SFP5V(I[)=0.0
                                                                            00003380
     FMG25V(11) =0.0
                                                                            00003390
     GRUTS(11)=0.0
                                                                            0003400
     SFRUTS(TI)=0.0
                                                                            00003410
     FMGBUT(TI)=0.0
                                                                            04003429
     GBU45(II)=0.0
                                                                             04003430
     >FRJAS(TI)#0.1
                                                                             04450010
     FMRJAS(TI)=0.0
                                                                             0003450
     GBH(11)=0.0
                                                                             00003460
     >FG 10 ( [ [ ] = U . U
                                                                             04003470
     FMS3U(II)=0.0
                                                                             01003480
 SAU CONTINUE
      EXAMINE SEGMENT OF INTEREST TO OFFER THE HUMBER OF VORTICES
      SEPARATING ON OR PRIDE TO IT
                                                                            00003490
     AXL=AXL+SFG_
                                                                             00003500
      DO 501 7=1+7WVX
                                                                             00003510
      IF (AAL.GT.ABS(GSEP(J))) 50 17 201
                                                                             0003520
      J-L=IML
                                                                             00003530
      60 10 Su3
                                                                            00003540
  201 CONTINUE
                                                                             00003550
  203 IF (JM1.51.0)65 TO 214
      NO VURTICES SEPARATING ON UP PATOR TO SEGMENT
                                                                             000356A
      GA41 (K) = 0.0
                                                                             00003570
      SF(<)=0.0
                                                                             0003580
      YMO4(K)=0.0
                                                                             01007590
      60 TU 200
                                                                             0n003600
  204 AXEMI = AXE - SEG
                                                                             01057610
      ISTART= 1
                                                                             01003620
      DO 205 IVS=1+ JM]
      DOES VURTER STADE BY DR PRIJE TO SESPENT
C
                                                                             00003630
      IF (AUS (GSEP (UVS) ) . 31.4 XLM] ) 30 10 20 c
      SEPARATED VORTICES PASSING OVER ENTIRE SEGMENT
                                                                             0003640
      IF (JVS. 91.2) 67 TO 511
      CIRCULATION ON SEGMENT DUE TO FIRST TWO VARTICES
                                                                             01003650
      VOS=## ((E) + ( (Axt 41 + (SEGL/2.)) = ARS (SEP (JVS)))
                                                                             0007660
      VOCL#VDSP+((D/2.) #SIN((HETAI))
```

```
00003670
      HOTS1=5 INT((V)C( **?.) *!(()//.) *COS(THFTATi) **?.))
                                                                             01003680
      GAH2C(JV5)#3A457(JV5) *C35(E)
                                                                             00003690
      510 OT 08
      CIRCULATION ON SEGMENT DUE TO STREET VARTICES
  811 JAC45=742-5
                                                                             01003700
                                                                             04003710
      DSP=(AXL 41+(S=GL//.))-445(GSEP(.IVS4*))
                                                                             00003720
      STG ###MT49((5)PT((4//++5UH)((4/?+) *#?++
                                                                             00003730
     1 (7/2.) 402.) 402.-(4/2.) 442.) -((1/2.) 4
     251N([HETAT)))/(845(35EP(JV5))-445(GCFP(JVCM2))))
                                                                             00003740
      tellnate (EVU) 9727) 28A- (ANDIC) NATO ( (SN 2VU) 9225) 28A) = M, MTK
                                                                             00003750
                                                                             04003761
     1/(TAH(5]GHA)-TAH(E))
    . XLF VEXTHO HARBO (OSEP (14542))
                                                                             00003770
                                                                             0003780
      IF ( 15P. 16 F. X. E 4) 90 . F.) 51 3
                                                                             0n003790
      VN5-=144(515M4) + (1441+ (563L/6.1) - +45(38FP(JVS)))
      VOC_#VUSP+((0/2.) *514(14ET#1))
                                                                             0003A00
      991-1=5:4T((V)C(++2.)+((H/C.)++2.))
                                                                             00003410
      CINCULATION OF SEPARAL DUE TO PROSE AND THANSITED IN BELAETA
      FORPL AND THURSON TRAUECTURIES
                                                                             CSBFOORD
      GAMPC (UVS) #3AMSV (UVS) #675 (5104A)
                                                                             00003930
      510 Li 08
                                                                             00003840
  613 VDSP#TAM(F) + ( (AxL 4) + (SEGL/C.)) TARE (SEP (JUS))
                                                                             0003950
      VDC_=VUSP+((D/2.)+S[V([HFTAT))
      POIST=SiRT((V7Ci ++2.)+((H/2.)++7.))
                                                                             00003860
      CINCULATION OF SECHENT OUR TO STREET VORTICES FOLLOWING THOMSON
      THAJECTORY
                                                                             01003971
      54420 (JVS) = 34 45V (JV3) *C05 (E)
                                                                             0003680
  612 RCA_EHUTST/)
      IF (RCAL, GT. SAULTM) 55 17 315
                                                                             00003690
      ADJUSTING INDUCED CINCULATION FOR PARTAL MERAY
                                                                             04003940
      SAMPU (11/5) = 34 PP ( JV 5) P, (114 4) 14-9CA_17GA AL YM1
                                                                             04003910
      60 10 316
                                                                             09003920
 315 GAM >C (UV 51 # J. 7
      SINE FORCE AND VANTUE ADMENT CHICILATIONS
                                                                             Un00393n
  316 SEPTIONS) =A4SIGAMPC(JVS)) PHHUTHENCOSEGU
                                                                             01003940
      IF (SAMPO ( NS) .GT. 7.7) SFPC (UVS) =-SEP* (UVS)
                                                                             0003950
      FMG,70(U)5)#6F30(U)5)+(4#6414+(5E5672.))
                                                                             00007961
C
      VNOTER SEPARATES ATTAL . H ) URDS OF SEGMENT
C
                                                                             01003970
  204 IF([5[40]. 63. 1) [5[47[*]VS
                                                                             04003981
      IF() VS. 3 F. 2167 TJ 514
C
      CTUCULATION ON DEMAINING PURTION OF SERVENT DUE TO EIRST TAN
C
      VONTICES
                                                                             01003990
      495>=TA ((5) + (AX) +A+5 (35EH (UVS)))///-
      ADC =A726+ ((U/S')+214(THELYI))
                                                                             00004000
                                                                             00004010
      RDISTasort((Vac: **?.) + ((())//+) *CHRITHFT4[i) **?+) ...
                                                                             01004020
      GPSV(JV4)=64MCV(JV5)+245(F)
                                                                             00004030
      60 17 517
      CINCULATION OF WEARTHING PURITOR OF SEGMENT DUE TO STREET MORTIMES
                                                                             00004040
  4-245=51 2VL 418
      DSD=(AHS(SSEP)UVS))+((ARL-AAS(GSEF)(IVS)))/2.011-AAS(GSEF(JVEMS))
                                                                             04004050
      SIGNA * ATANCISONT (CH/). . SURT ((4/7.) 007. .
                                                                             00004060
     1 (7/2.) +02.)) +07. - (4/2.) ++7.) - (17/2.) +C1 -(THETATI))/
                                                                             00004079
                                                                             00004080
     2 (ART LASEMIJUSI) - 147 (USEP (UVSM2111))
      XTHUM = (AHS(SSPP(JVSAP)) + [AH(STSAA) - ARE(SSEP(JVS)) + TAN(F)) P
                                                                             00004090
                                                                             00004100
     1 (TAUESESMA) - TAM(E))
                                                                             00004110
      115P2VL) 4:26) 284 - POPTX = V31X
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		Bun of American	
		IF(1SP. ST. ALEN) SU TO DIS	00004120
		VDS2 # TA"(\$13MA) # ((4KL - #851995P(1V91)1/2+)	00004130
		VOCL = VOSP +((D/2.) + SI+(THE(AT))	00004140
		ROIST = SURT((V)C_P=2.) + ((M/2.).+2.))	00004150
٠		CIPCULATION ON REMAINING PURITUM OF SEG FUT DUE TO VORTICES	011004130
•		TRANSITIONING RETHEEN FUMPL AND THOMSON TRAJECTORIFE	
		GPSV(JVS) = GAMSV(JVS)+CUS(513M4)	00004160
	_	60 10 615	0n004170
•	616	VOSP = TAN(E) + ((ARL - ARS(GSED()VC)))/2.)	0n004180
		VOCE = VUSP + ((D/2.) + SIN([HETAT])	0n004190
		RDIST = SONT((VDC_0000) + ((M/2.)000.))	0004200
C		CINCULATION ON DEMAINING PURTION OF SEGIFFIT DUE TO MURTICES	
:		FAL UNING THOUSON TRAUSCTIMY	
		6P5V(JV5) = 64M5V(JV5) + CUC(E)	00004210
	615	RCAL # PUISIA	00004220
	-,-	IFERCAL OT . SAULIMIST TO ST!	00004230
C		ADJUSTING INDICED CIRCULATION TO ACCOUNT FOR RADIAL DECAY	01,004201,
•		3854(JVS) #3254(JVS) #((744_1474CA)) / 744 FOR HANDE SECTION	.0004240
		· · · · · · · · · · · · · · · · · · ·	
		30 TO 118	0004250
_	317	GP\$/1J4/1=0.0	0n00426ij
C		SIDE FURCE AND YAWING ADMENT CALCILATIONS	
	318	SFPSV(JVS) = ABS (3PSV (JVS)) = HHUINF+VC+ (AXL-ARS (GSEP (JUS)))	0,004270
		1F(3PSV(JVS)+3T.0+J)5°PSV(JVS)==S°PSV(JVS)	0n004280
		F4G25V(J45) #5FP5V(J45) + (A45(USEP(JVC)) + ((AX) +A45(GSFP(JUS)))/2.1	1100004290
	2115	CONTINUE	0^004300
C		GO TO 314 IF TO VORTICES SCHARATE OF SERVENT OF INTEREST	
		IF(15TAPT.E3.0)30 TO 219	0ng0431n
C			-
C		CALCULATE CIRCULATION LAUDUED BY A GHOWING VORTER FOOT THE	•
C		REGINALIO OF THE SESMENT OF TO POTAT OF SEPARATION	•
C			
			• • •
		Un 20/ Varstart, Jul	0004320
		Un 20/ (=157817.)41 IF: 4.67.2:60 to 209	0n004320 0n004330
		PERSON TO POST	01004330
c		IF(N+GT, 2) 60 209 IF(N+LE, 2, 40, A=5 (35E2(N))+3T, NOSEL) 60 TO 209	
C		PERSON TO POST	01004330
		IF(N.GT.2)60 tO 209 IF(N.LE.2.A.U.A.35(35E2(N)).3T.NOSTLIGO TO 209 NO CHCOLITION INDUCED BY PUTENTIAL VORTICES UP TO BOINT OF	0n004330 0n00434n
		IF(N+GT, 2) 00 70 209 IF(N+LE, 2, A VD, A PS (35E2(N))+ST, NOSTLIGO TO 209 NO CHROILITION INDUCED BY PUTENTIAL VORTICES UP TO DOINT OF SEPARATIO URUS (N) = 1.0	0n004330 0n00434n 0n004350
		IF(N.GT.Z)GO TO 209 IF(N.LE.Z.AND.ARS(GSER(N)).ST.NOSTLIGO TO 209 NO DIRCULATION INDUCED BY PUTENTIAL VORTICES UP TO DOINT OF SEPARATION UP TO DOINT OF SEPARATION SEPARATION OF SEPARAT	0n004330 0n00434n 0n004350 0n00436n
		IF(N.GT.Z)GO TO 209 IF(N.LE.Z.AND.ARS(GSER(N)).ST.NOSTLIGO TO 209 NO CINCULATION INDUCED BY PUTENTIAL VORTICES UP TO DOINT OF SEPARATIO URUTS(NIR).O SERJIS(4)=0.0 FMG3UT(4)=0.0	0n004330 0n00434n 0n004350 0n00436n 0n004370
		IF(N.GT.Z)GO TO 209 IF(N.LE.Z.AVD.ARS(GSEP(N)).ST.NOSTLIGO TO 209 NO CIHCILITION INDUCED BY PUTENTIAL VORTICES UP TO DOINT OF SERABATIO URUIS(NIR).O SERJIS(J)=J.O FMGJUT(NIR).O 30 TO 207	0n004330 0n00434n 0n004350 0n00436n 0n004370 0n00438n
. C		IF(N.GT.ZiG) to 209 IF(N.LE.Z.A.V).ARS(GSEP(N)).ST.NOSTLIGO TO 209 NO CIHCULITION INDUCED BY PUTENTIAL VORTICES UP TO DOINT OF SERARATIO URUIS(NIR).O SERJIS(J)=J.O FMGJUT(4)=0.0 30 TO 21/ IF(AKL4).LT.NOSEL).O [) 22/	0n004330 0n00434n 0n004350 0n00436n 0n004370
C		IF(N.E.2.AVD.ARS(GSEP(N)).ST.NOSTLIGO TO 209 NO CIHCULATION INDUCED BY PUTENTIAL VORTICES UP TO DOINT OF SERARATIO URUIS(NIR).O SERJIS(1)=0.0 FMG3UT(4)=0.0 30 TO 21/ IF(AKL4).LT.NOSEL).O [) P2/ CIRCULATION INDUCED BY FIRST TWO VOCTICES SEPARATIOS PART THE	0n004330 0n00434n 0n004350 0n00436n 0n004370 0n00438n
CCC		IF(N.E.2.AVD.ARS(GSEP(N)).ST.NOSTLIGO TO 209 NO CINCULATION INDUCED BY PUTENTIAL VORTICES UP TO POINT OF SERMATIO UNUTS(NIFI.O) SERVIS(4)=0.0 FMGUT(4)=0.0 30 TO 21/ IF(AKL41.LT.NOSEL).D) [) 22/ CIRCULATION INDUCED BY FIRST TWO POSTOCES SEPARATIOS PART THE SHOULDED NO SITH THE REGREAT LYING ENTIRELY ON THE CYLINDRICAL	0n004330 0n00434n 0n004350 0n00436n 0n004370 0n00438n
C		IF(N.E.2.AVD.ARS(GSEP(N)).ST.NOSTLIGO TO 209 NO CIHCULATION INDUCED BY PUTENTIAL VORTICES UP TO POINT OF SERMATIO URUIS(NIR).O SERVITS(1)=0.O FMGUT(4)=0.O 30 TO 27/ IF(AKL41.LT.NOSEL).O T) P2/ CIRCULATION INDUCED BY FIRST TWO VOCTOES SEPARATIOS PART THE SHOULDFO 180 XITH THE REGREAT LYING ENTIRELY ON THE CYLINDRICAL PORTION OF 3007	0n004330 0n00434n 0n004350 0n00436n 0n004370 0n004380 0n004390
CCC		IF(N.E.2.AVD.ARS(GSEP(N)).ST.NOSELIGO TO 209 NO CIHCULATION INDUCED BY PUTENTIAL VORTICES UP TO DOINT OF SERMATIO UNUTS(NIR).O SERVITS(1)=0.O FMGUT(4)=0.O 30 TO 27/ IF(AKL41.LT.NOSEL).O I) P2/ CIRCULATION INDUCED BY FIRST TWO VOCTOES SEPARATIOS PART THE SHOULDER THE THE GROWLY LYING ENTIRELY ON THE CYLINDRICAL PORTION OF BODY GAX_MIR(GAMPROV(MFP)PSIN(ADAR(1)).((ANIM)=NOSEL).PGRATE))	0n004350 0n004350 0n004350 0n004360 0n004370 0n004380 0n004390
CCC	200	IF(N.E.2.AVD.ABS(GSEP(N)).ST.NOSELIGO TO 209 NO CIHCULATION INDUCED BY PUTENTIAL VORTICES UP TO DOINT OF SERARATIO URUSS(N)=1.0 SERJIS(1)=1.0 FRESUT(4)=0.0 30 TO 27/ IF(AKL41.LT.NOSEL).SO [) P2/ CIRCULATION INDUCED BY FIRST TWO MODITIES SEPARATIOS PART THE SHOULDED NO MITH THE GREWENT LYING ENTIRELY ON THE CYLINDRICAL PORTION OF MODY GAX_MIR(GRAMPSEV(NEP)*SIN(ADAR(T)).*((ARIMI=NOSEL)*GRATT)) IF(AKL4).GT.ARLE).SAK_41=(GRAMPSEV(NE*DESTM/ADAR(T)).*	0n004350 0n004350 0n004350 0n00436n 0n004370 0n004380 0n004390
CCC	200	IF(N.E.2.AV).ABS(GSEP(N)).BT.NOCTLIGO TO 209 NO CIHCULATION INDUCED BY PUTENTIAL VORTICES UP TO DOINT OF SERARATIO URUIS(NIB).O SERJIS(1)=0.0 FMBJUT(4)=0.0 30 TO 207 IF(AKL41.CT.NOSEL).D TO P27 CIRCULATION INDUCED BY FIRST TWO VOCTICES SEPARATIOS PAST THE SHOULDED NO FITH THE REGRENT LYING ENTIRELY ON THE CYLINDRYCAL PORTION OF 3007 GAX_MIR((GAMP20V(MED)0CIN(ADAR(T))).((AXIM1-NOSEL)0GATT)) IF(AKL4).GT.AR(E).SAK_41=(GAMP20V(MED)0CIN(ADAR(T))). If(AKLE-NOSE_)0GATE).((AXIM1-AA)E)0CPATEO.4)	0n004350 0n004350 0n004350 0n004360 0n004370 0n004380 0n004400 0n004400 0n004410 0n004420
CCC	200	IF(No.E.2.AND.ARS(GSEP(N)).ST.NOSTLIGO TO 209 IF(No.E.2.AND.ARS(GSEP(N)).ST.NOSTLIGO TO 209 NO CINCULATION INDUCED BY PUTENTIAL VORTICES UP TO DOINT OF SERABATIO URUSS(N) = 1.0 SERATE() SERATE	0n004350 0n004350 0n004360 0n004360 0n004380 0n004390 0n004400 0n004410 0n004420 0n004430
CCC	200	IF(NotE, 2, A ND, A A S (35E ? (N)) + ST. NOSELYGO TO 209 NO CINCULATION INDUCED BY MUTENTIAL VORTICES UP TO DOINT OF SERABAT! UNUTS(N) = 1.0 SERAT() SERAT() SERAT() ONUTS(N) = 1.0 FREGUT() = 1.0 FREGUT() = 1.0 FREGUT() = 1.0 CIRCULATION INDUCED BY FIRST TWO MODITICES SEPARATION PAST THE SHOULD POINT OF THE THE SHOULD POINT OF THE THE SHOULD POINT OF BOTH THE CYLINDRICAL PORTION OF BOTH THE SHOULD POINT ON THE CYLINDRICAL PORTION OF BOTH THE SHOULD POINT ON THE CYLINDRICAL PORTION OF BOTH THE SHOULD POINT ON THE CYLINDRICAL PORTION OF BOTH THE SHOULD POINT ON THE CYLINDRICAL POINT ON THE CYLINDRICAL POINT ON THE CYLINDRICAL SERVENCE OF SHOULD POINT ON THE CYLINDRICAL SHOULD POINT ON THE CYLINDRE SHOULD POINT ON THE SHOULD POINT ON	0n004350 0n004350 0n004350 0n004360 0n004370 0n004380 0n004400 0n004410 0n004420 0n004430 0n004440
CCC	200	IF(NotE, 2, A ND, A A S (35E2(N)) + ST. NOSELIGO TO 209 NO CINCULATION INDUCED BY PUTENTIAL VORTICES UP TO DOINT OF SERABATIO URUSS(N) = 1.0 SERABATIO URUSS(N) = 1.0 FRESUTS(1) = 1.0 FRESUTS(1) = 1.0 FRESUTS(1) = 1.0 CIRCULATION INDUCED BY FIRST TWO MODITICES SEPARATION PAST THE SHOULD POWER OF THE THE SEGMENT LYING ENTIRELY ON THE CYLINDRICAL PORTION OF BODY FOR SHOULD POWER OF SHOW OF SHOULD POWER OF SHOW OF SHOULD POWER OF SHOW OF SH	0n004350 0n004350 0n004360 0n004360 0n004370 0n004380 0n004400 0n004410 0n004420 0n004430 0n004450
CCC	200	IF(Note, 2.8 ND. ARS (35E2(N)).3T.NOSELIGO TO 209 NO CINCILITION INDUCED BY MUTERTIAL VORTICES UP TO DOINT OF SEPARATO URUSENES SERVIS(1)=1.0 FRESUT(4)=0.0 30 TO 27/ IF(ARL41.2T.NOSEL).30 T) P2/ CIRCULATION INDUCED BY FIRST TWO MOCTICES SEPARATOG PAST THE SHOULDED THE THE SEGMENT LYING ENTRELY ON THE CYLINDRICAL PORTION OF SHOP GAN_MIR((3AMPROV(NEM)*SIN(ADAR(1))).((ARD-1-NOSEL)*GARTE)) IF(ARL4).ST.ARLE).SAK_41=(SAMP2*VINF*DIRSTNADAR(7))). I((ARLE-NOSE_).GGARTE).((ARLM)*ANLE).SHATE*O.4) SSURI(GA 402*VINE*).SIN(ADAR(1))).((ARC(3SEP(N)).NOSEL)*3RATE*) IF(ARS(3SEP(N)).GT.NALE).SPECSMEDAMPROVINF*DIRSTN(ADAR(7)). I((ARLE-NOSE_).SGRRTE).((ARS(3SEP(N)).NATE*O.4) GRUTS(4)=(GSP*GAR_MI)/2.	0n004350 0n004350 0n004350 0n004360 0n004370 0n004380 0n004390 0n004400 0n004420 0n004420 0n004450 0n004450 0n004460
CCC	200	IF (4.6T.236) TO 209 IF (4.6E.2.A 4D.ABS (35E2(N)).5T.NOSTLIGO TO 209 NO CIHCULATION INDUCED BY PUTENTIAL VORTICES UP TO DOINT OF SEPARATO BRUTS (NIBLE). SERVIC (1) = 1.0 FROSUL (4) = 0.0 30 TO 207 IF (4KL41T.NOSEL).30 TO 227 CIRCULATION INDUCED BY FIRST TWO MORTICES SEPARATOR PAST THE SHOULDFD 140 AITH THE SEGMENT LYING ENTIRELY ON THE CYLINDRICAL PORTION IN AITH THE SEGMENT LYING ENTIRELY ON THE CYLINDRICAL PORTION OF BOTH THE SHOULDFD 140 AITH THE SEGMENT FOR SEPARATOR (1)). IF (4KL41T.ABLE).344BICAMMP20VINFODOSTNIADAR(T)). If (4KLE-NOSE.).6GHATE).6(AKLM1-AALE).8GHATERO.4) SSUBLIGG 4020VINFODOS).4(ANAM(1)).6(ARC (3CEP(N)).NOSEL).8GHATER). IF (4KLE-NOSE.).8GHATE).6(ARC (3SEP(U))ARC).8GHATERO.4) GHUTS (4) = (0.5P.6GAR.M1).72. CAL EURO (N.CASE)	0n004350 0n004350 0n004350 0n004360 0n004370 0n004380 0n004430 0n004420 0n004420 0n004430 0n004450 0n004450 0n004460
CCC	200	IF (4.6T.204) 10 209 IF (4.6E.2.AV). ABS (35E2(N)). ST. NOSTLING TO 209 NO CIHCULATION INDUCE) BY PUTENTIAL VORTICES UP TO DOINT OF SEPARATIO BRUTS (NIELO) SERVIS (NIELO)	0n004350 0n004350 0n004350 0n004360 0n004370 0n004380 0n004430 0n004420 0n004420 0n004430 0n004450 0n004450 0n004460 0n004460
CCC	5 11	IF (4.6T. 2.60) 10 209 IF (4.6E.2.4N).ABS (35E2(N)).ST.NOSTLIGO TO 209 NO CINCILATION INDUCED BY MUTENTIAL VORTICES UP TO DOINT OF SEPARATION UNITS (4)=1.0 FROM TO (4)=0.0 SO TO 21/ IF (ARL41.10N INDICED BY FIRST TWO MODITICES SEPARATION PART THE SHOULDFO 140 WITH THE SEGMENT LYING ENTRELY ON THE CYLINDRICAL PORTION IF 300Y GAM_MIR((3AMP20)(ME0)*CIN(ADAR(T)).((ANIMI=NOSEL)*GRATE)) IF (ARL41.5T.ANIE) 3AK_41=(GAMP20VINF**DOSTMAR(T)). I((ARLE-MOSE_)*GRATE)*((AR_M)**ANIE)*GRATE**O.4) GSU**((GAMP20VINF**)*S]*((ANAM(L)))**((ANG(GREP(N))**NOSEL)**GRATE*)) IF (AND (35FM(N)).GT.AX.E)GSM**(GAMP20**INF**O.45) GSU**((GAMP20VINF**)*S]**((AMS(SSEM(I)))***(SAMP20**INF**O.45) IF (AND (35FM(N)).GT.AX.E)GSM**(GAMP20**INF**O.45) GMUTS(4)***(GAMP3)**(GAMS(SSEM(I))****(GAMP20**INF**O.45) GMUTS(4)***(GAMS(SAME)***(GAMS(SSEM(I))*****(GAMP20**INF**O.45) GMUTS(4)***(GAMS(SAME)***(GAMS(SSEM(I))*****(GAMTE**).A) GAL_EURU(****(GAMS(SAME)***) IF (GASE.***FU.O.46) IF (GASE.**FU.O.46) IF (GASE.**FU.O.46) IF (GASE.**FU.O.46)	0n004350 0n004350 0n004350 0n004360 0n004370 0n004380 0n004430 0n004420 0n004420 0n004430 0n004450 0n004450 0n004460 0n004460 0n004460
CCC	211	IF(4.6T.2)40 to 209 IF(4.6E.2.A.4U.A.A.5 (35E.2(4))	0n004350 0n004350 0n004350 0n004360 0n004370 0n004380 0n004430 0n004420 0n004420 0n004450 0n004450 0n004450 0n004460 0n004460 0n004450 0n004450
CCC	211	IF(Y*LE, 2.A YD, ARS (35E 2(N)) * \$1.NOSTLYBO TO 209 IF(Y*LE, 2.A YD, ARS (35E 2(N)) * \$1.NOSTLYBO TO 209 NO CINCULATION INDUCED BY MUTENTIAL VORTINES UP TO DOINT OF SEPARATION AND SERVICE (N) = 1.0 SERVICE (N) = 1.0 SERVICE (N) = 1.0 FREQUENTION INDUCED BY FIRST TWO MODITIES SEPARATION PAST THE CIRCULATION INDUCED BY FIRST TWO MODITIES SEPARATION PAST THE SHOULD FO 140 MITH THE SEGMENT LYING FINITHELY ON THE CYLINDRICAL PORTION OF ADDY GAX_MIR((3A MPDON)(NFO) PRIN(ADAR((1))) * ((AND) = NOSEL) * GRATE)) IF(ARLA) * \$1.A * LE	0n004350 0n004350 0n004350 0n004360 0n004370 0n004380 0n004390 0n004410 0n004420 0n004420 0n004450 0n004450 0n004460 0n004460 0n004460
CCC	211 211	IF(Note, 2.4 ND, 495 (35E2(N)) + 3T NOTELIARD TO 209 IF (Note, 2.4 ND, 495 (35E2(N)) + 3T NOTELIARD TO 209 NO CINCIDATION INDUCED MY MUTERITAL VORTINES UP TO DOINT OF SEPARATION AND TS (N) = 1+0 SERATE (N) = 1+0 FREQUITY (N) = 1+0 FREQUITY (N) = 1+0 FREQUITY (N) = 100 TO 21 IF (4AL41 + LT NOTEL) = 1 1 22 CIRCULATION INDUCED MY FIRST TWO VOCTORS SEPARATION PART THE SHOULD POUNT INDUCED MY FIRST TWO FINTERLY ON THE CYLINDRICAL PORTION IN MOSEL PROPERTY OF THE CYLINDRICAL PORTION IN MOSEL PROPERTY OF AN ALE SAMPLE (SAMPLE VINER POUNT OF ANALE) AND ARROYS (NEW YORK (N)) + ((AALM) + AUSY (NEW YORK (N)) + ((AALM) + AUSY (N) + AUSY (N) + ((A	0n004350 0n004350 0n004350 0n004360 0n004370 0n004380 0n004430 0n004420 0n004420 0n004450 0n004450 0n004460 0n004460 0n004460 0n004460 0n004460 0n004450 0n004450
CCC	211 211	IF(Y*LE, 2.A YD, ARS (35E 2(N)) * \$1.NOSTLYBO TO 209 IF(Y*LE, 2.A YD, ARS (35E 2(N)) * \$1.NOSTLYBO TO 209 NO CINCULATION INDUCED BY MUTENTIAL VORTINES UP TO DOINT OF SEPARATION AND SERVICE (N) = 1.0 SERVICE (N) = 1.0 SERVICE (N) = 1.0 FREQUENTION INDUCED BY FIRST TWO MODITIES SEPARATION PAST THE CIRCULATION INDUCED BY FIRST TWO MODITIES SEPARATION PAST THE SHOULD FO 140 MITH THE SEGMENT LYING FINITHELY ON THE CYLINDRICAL PORTION OF ADDY GAX_MIR((3A MPDON)(NFO) PRIN(ADAR((1))) * ((AND) = NOSEL) * GRATE)) IF(ARLA) * \$1.A * LE	0n004350 0n004350 0n004350 0n004360 0n004370 0n004380 0n004430 0n004420 0n004420 0n004450 0n004450 0n004460 0n004460 0n004460 0n004460

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IF (38HTS (1) -61-1-3) 5F3 ITS (N) =-5F4 ITS (N) TROUGHT PROMISES TO SDC
                                                                                00004530
                                                                                00004540
      FMG-3UT(1)=SFH 1T5(4) # (4 (LM1+((AUS(35FP(N))-A+LM1)/2.4))
      TUS C1 00
                                                                                00004550
  208 IF (4.67.4) GO TO 210
                                                                                00004560
      CIRCULATION INDICED HY GROWTH OF INTITAL TWO STREET VORTICES
      EXPERIENCING MODIFIED SHOWIN HATE
C
                                                                                00004570
      Muc zita
                                                                                00004580
      DIFF#(AAS(GSE>(V))) - (AAS(GSEP(MAP)))
                                                                                0004590
      GRADJ4=3A41/UTFF
                                                                                0004600
      GAX_M1=GRAD34+(AX_M1-445(GSEP(NYZ)))
      IF (445 (GSFP (N 12)) . 31.4xLE) 64XL 41 = n., +GRAD = 4+ (AXLM1 - A45 (35EP (N42))) 00034610
      IF (AXI 4) GT. AxEF. AND. AGGGSEP (NAP) . I T. AXI E) GAXEMI = (AX_E-
                                                                                00004520
                                                                                00004630
      TARG (USED (VM2) ) ) 4644 ) 3+) + ( (AXLM1-AXLE) 467A03440.4)
                                                                                00004640
      SSP=URAH344 (ARS (GSE P(N)) - 185 (GSEP (N-2)))
      IF (485 (45EP (N42)).71.44LE) 65P=0.4073A0740(ARS (GSEP (N))+185 (45EP (N400004650
                                                                                00004660
     12)))
      IF (AUS (GSEP (N)) .GT. AX_E.AYU.AHS (GGEO (NYP)) .LT.AXLF) GSP= ( (AX) E
                                                                                00004670
      1-A45 (GSFP(N42)) 1 + 538034) + ( (ABS (GSFP(4)) ) - 44LF) + GRAN34+0.4)
                                                                                00004680
                                                                                00004690
      XPOINT = AX_MI + ((AHS(GSEP(N)) - AVIMI)/7.)
      CAL_ AY7 (H. D. THETA] . A 35EP (H) . GSFP (N) . GSFP (N42) . XP7 [NT. Y. Z.A] . A2)
                                                                                00004700
                                                                                00004710
      RDIST = SORT((Y \bullet + 2 \bullet) + (Z + + 2 \bullet))
                                                                                00004720
      RCA_ = PDIST/3
                                                                                00004730
      IF (RCAL.GT. 3A4LTM) 30 10 620
      ADJUSTING CIRCULATION TO ACCOUNT FOR RATTAL DECAY
                                                                                00004740
      GAXLM1 = GARLWI + ((GAMLIM - RCAL)/GAMLIM)
      GSP = GSP 4 ((GAM_I 4) - HCAL)/GAM TM1
                                                                                00004750
      GAX_M) = GAXL41 +COS(41) + CUS(AP)
                                                                                01004761
      GSP = GSP + ChS(Al) + COS(A2)
                                                                                0n004770
                                                                                01004780
      60 TU 211
                                                                                0004790
  SIO MMS=N-5
      CIRCULATION INDUCED AT SROWTH OF STOFET VARTICES HAVING NOWTHAL
C
      GROATH RATE
                                                                                00004800
      GAX_MI=GRATE+(AxL4)-435(GSEP(VM7)))
      TF(aus(GSFP(N42)).ST.AxLE)GAXLM1=n.4+GRATF+(AXL41=ABS(GSEP(NM2))) 00004810
                                                                                00004820
      IF (AALM) -GT. AXLE. AND. AGS (GSEP (NMP)) -LT. AXLE) GAXLMIE / (AX_E
                                                                                00004830
     ]-4A5(GSEP(N42)))#34A}ED+((AXLM1-4XLE)#G45TE#U.#)
      GSP=GRATE+(AHS(GSEP(N))-AHS(GSEP(NM2)))
                                                                                Un004840
      IF (ABS (SSFP (NUZ)).SI.AXLE) USP=U.4+BOATE+ (ABS (GSEP (N))-A3S (GSEP (M200004850
                                                                                00004860
     1)))
      IF (ABS (GSEP (N)) . GT. AX_E. AYU. ABS (GSED (NYP)) . LT. AXLE) & SPE ( (AYI'E-
                                                                                00004870
     1485 (GSEP ( VM2) ) ) +GRATE) + ( ( Abs ( GSFP ( N) ) -AXLF) +GRATE + 0_4)
                                                                                On004880
      XPOINT = AXLM1 + ((A+5(GSEP(N)) - AYLM1)/>.)
                                                                                0n00489n
      CAL_ XYZ (H.) - THETAI - A SEEP (N) - BSEP (N) - BSEP (NM2) - XP71-1T. Y. Z. A 1 - A2)
                                                                                00004900
                                                                                01004911
      90151 = SiHT((Y4+2.) + (Z++2.))
                                                                                0004920
      RCA_ = 4DIST/>
                                                                                00004930
      IF (RCAL.GT.SAULTM) 37 17 620
      GAX_M1 = GAXLW1 # ((GAWLIM - RCAL)/CAMLTM)
                                                                                00004940
      ADJUSTING CIRCULATION IN ALCOUNT FOR RADIAL DECAY
                                                                                00004950
      GSP = GSP + ((GAM_14 - RCAL)/GAM THE
      GAX_M1 = GAXLG1 +075(41) + CUS(42)
                                                                                00004960
      GSP = GSP + 'ChS(A1) + COS(A2)
                                                                                00004970
                                                                                0n00498n
      60 10 211
      CIRCULATION INDUCED BY FIRST TWO VOSTICES SEPARATIME PAST THE
C
      SHOULDER AUT WITH A MUNICIPAL OF THE SEGMENT ON THE MASE
  227 GAX_M1=0.8
                                                                                00004990
      GNOSEL=GAMP2+VIMF #D#SIN(ADAR(I))
                                                                                00005000
      GSP={(GAMP?#VINF#)#31 W(ADAH(1)))+((AHS(GSEP(N))-NOSEL)#3RATE))
                                                                                00005010
                                                                                0005020
      IF(4HS(GSEP(N)).GT.4X_E)GSP=(GAMP>#VINF#D+SFN(ADAP(+1))+(
```

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MAIN

	1	(AX_E-NOSEL) *GRATE) * (CABS (USEP (N)) = AXCE) *A*BRATE)	00005030
		GB(15(N) ≠ (U)OSEL + 352) /2.	00005040
		CAL_ EURO (N-ICASE)	00005050
,		IF (ICASE. EU. UIGO FO 240	00005060
_	241	GBUTS(N) == 63UTS(N)	0nG05070
Ĵ		SIDE FURCE AND YAMING MOMENT CALCULATIONS	
	240	SFRUTS(N) =A+5(GHUTS(N)) #HHUINF#VC#(AHS(GSEP(N)) =NOSEL)	0n005080
		IF (38UTS (N) . GT. 0 20) 3F 30 TS (N) =- SFR 10 (1)	00005090
		FMG3UT(N)=SFB: C(N) * (NOSEL* ((ABS (GSFP (N)) = NOSEL) / 2. n))	00005100
_ '	207	COMTINUE	07005110
		CALCULATE CINCULATION INDUCED BY A CROWING VORTER FAUR THE BOINT OF SERRATION TO THE END OF THE SEGUENT	
•		140-1514121=1 SIS QU	01005120
		'IF(0T,2)GJ TO 214	00005130
		IF (L.LE. 2. A VD. A45 (33E2(L)) . ST. VOSELIGIT TO 214	00005140
		IF(_+FU.2)60 to 215	00005150
;		CIRCULATING INDUCED BY SHOWER OF THEPR VIOLEX	
		DIFF=4HC(35EP(3))-4 10 (35EP(1))	00005160
			00005170
		GAXL#GH2D3# (AVL~A35 (35FP(1)))	00005180
		IF (ABS (GSEP(1)) GE. 4x_E) G4XL=0.4+38313+(AVL-ABS (GRE=11)))	00005190
		IF (AUS ()SEM (1)) . LT. AX . E. ANU. MXL. GT. AXLF) GAXL = ((AXLE . A) (GSE = (1)))	0005200
	•	1GPA) 3) + (J. 4 + G 2A) 3 + (AA AALE))	01005210
		G5P=U.U	0005220
		LP2=L+2	0005230
		XPOINT = AHS(SSEP(L))+((AXL-AHD(SSED(L)))/2.)	00005240
		WAL XYZ (4.) + THETAI + ABSEM (LPZ) + GCFP (LPZ) + GSFP (L) + XPAINT + Y+Z+AI+42)	01005250
		PDIST = SONT((Y***:)+(;**/*))	04005260
	•	RCA_ = AUIST/1	Un005270
		IF (RCAL, GT. 3A WLTM) 33 TO MPI	00005280
:		ADJUSTING INDUCED CINCULATION TO ACCOUNT FOR RADIAL DECAY	
		GAX_ = GAAL+((GAM_I +- ?CAL)/GAMLT")	0005290
	•••	GAX: # GAYL + COS(A1) + COS(A2)	00005300
	210	GBIJA5 (L22) = (6ax(+353)/2.	0005310
		CAL EURU(LPZ.ICASE)	05627000
		IF(ICASE.EU.0)60 TO 242 GO TU 243	01005330 01005340
	6 2 3	GBUAS(LP2) =0.0	0n005350
		GBUAS(L22)=-G3UAS(_22)	0005360
	E 7 J	SIDE FORCE AND YOURS UND HOUSE IT CALCULATIONS	-10-33-0
	26,	SFRJA=([HZ]=ARS(G3J45([PZ)) #HHUT':=#HC#(nt) =ABS(3SFP(L)))	00005370
		IF (381145 (LP2) . GT. J. J) SEHUAS (LP2) =- SCHUAS (1 P2)	00005380
		FMBJAS(LP2) =SFBHAS(_P2) + (ABS(GSFP(L))+((AVL-ABS(GRFC(L)))/2_1)	01005390
		60 10 212	00005400
		CIRCULATION INDUCED BY GHOMEN OF FOOTH MODIFA	
	215	DIFF2=44S(GSE>(4))-495(GSEM(2))	01005410
		GRA 74=GA41/)[=F7	Un005420
		GAX_=GRAD4#(A+L_A35(3>EP(2)))	00005430
		IF(aBS(aSFP(2)).GE.AX_E)GAALFO.4+aAN4+(AVL-ABS(GSED(2)))	00005440
		IF (ABS (GSFP(2)).LT.4X_F.AVU.AXL.GT.AKLE1GAXI,#((AALE.ABS(GSFD(2)))	
		1GRA)+)+(0,4#GRAD4*(4X_HAXLE))	0005460
,		G5P=0.0	01005470
		[b5=[+5]	01005480
		APOINT = ABS(SSEP(L))+((AXL-ABS(GRED(L)))/7.)	0,005490
		CALL XYZ(H+)+THF[4]+A35EP(LP2)+95=P(LP2)+95FP(L)+YPAINT+Y+Z+A1+82)	
		RDIST = SJHT((Y++2.)+(/++2.))	01005510

		MAIN	EST QUALITY PRACTICABLE
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		RCA_ = 30 ISI/7	
		IF(?CAL. 01.3A 4L14) 37 1) 621	01005530
C		ADJUSTING INDICED CIRCULATION IN ACCOUNT FOR	RADIAL DEGAT
		SAXL = GAXLO((GAM_I4-RCAL)/SAMLIM)	0005540
		BAXL = GAXL + COS(A1) + COS(A2)	0005550
		60 10 516	0005560
C		CIRCULATION INDUCED BY STHEET VONTEY FXPEDIEN	TAR MULTUEL BOOMIS
C		RATE	00005570
	214	BAX_RGRATE*(AxL=A55(SSEP(L)))	0005580
		LP2=L+2	
		IF(AUS(GSEP(L)).GF.AA.E)GAAL=U.4454ATE4(AYL-AG IF(AUS(GSEP(L)).LT.AA.E.AND.AXL.GT.AXLE)GAXL=	
		IGRATE) + (0.4+G3ATE+(4A_+AXLE))	0005610
•		GSb=n*0	0005620
		ABOIN! = ABS(RSEP(L))+((AXL-ABS(RSED(L))))/2.)	0005630
		CAL - XYZ(H+)+THETA[+43SEP(LPZ)+RSEP(LPZ)+RSEP	(L) + YPnINT - Y - Z - A1 - 42) 0005640
		RDISE = SORT((Y++2.)+(Z++2.))	0005650
		RCA_ = AUTST/7	01005660
		IFERCAL GT. SAMLIMIST 11 621	0005670
		GAX_ = GAXLO((GAM_I4-4CAL)/GAMLTM)	0005680
		GAX_ # GAXL + ChS(A1) + ChS(A2)	0,005690
		6n ru 216	0005700
	515	CONTINUE	0005710
C			N
C		IF ISTANT DOES NOT FOULL UMIT THIS MEANS THAT	A) SKAMING VORILLED
Ç		CAN PASS OVER THE FULLILENGTH OF THE SEGMENT . CIRCULATION CALCULATIONS FOR THE SEGMENT . RE	1040 E-F. 60 +0 221
C		- ************************************	
C		IF(ISTADT.NE. IM1) 50 TJ 221	00005720
c		for its into its interest of the contract of t	
C		LAI CULATE GROUTH OVER SEGMENT DUE TO A STUGIE	VORTER GROWING
·c		OVER THE ENTIRE SERRENT LENGTH	
Č			
		JNEKT=15faRT+1	06005730
		IF (JNEXT . EQ. 2) GO TO 21 ?	0005740
		IF (JNEAT . ST. 2160 F) 220	0n005750 0n00576n
	514] IF 1441. GT. NOS=L.A+). 44L41. 6E+NOSE_1 GO TO TE	0005770
_		IF(AAL-ST-405FL)G) 10 226	0,00-777
С	•	SEGMENT ENTIFIER ON MUNE GRUCUMENT)=0.0	0605780
		60 tu 224	00005790
c		CIRCULATION INDICED DY SECHENT BY GOOMEN OF SE	
C		THE SECRET STARTING IN THE NOSE	
-	224	SAX MI =U-II	01005800
		GNOSEL#BAMP2#VINF#9#51V(ADAR(I))	0005810
		GAX = ((SAMP 2 W / WF P) #51 V (A)AR (1)) + ((AXL -M)SFL	1+3HATE)) 0005820
		IF (AAL .GI.AKLE) GAKLE (344P2 VINF + 0 + 51 V (A 7AD (T))	0005830
	•	I ((ATEF-NULE_) &GOATE) + ((ATE-ATE) + TRATE + TALE)	0005840
		GRIE(UNE cf) = (G \ Xi + >475 EL) / 2+	0005850
		CAL FORU (UNEXY . ICASE)	0n005860
		IF (ICASE . FU. UIGO T) 256	0005970
_		F BBH (UNEXT) =-Galifica VEXT)	0005880
C	•	SIDE FURCE ANY YAATYO ADMENT CHICILATIONS	75FL) 0n00589n
	7 4 4	SEGULLYEXT) = (HC(F))(JNEXT)) PHMOT VF + VC+ (AVE - NO	AUAND AUAND AIL
	C 40	THE PROPERTY OF THE STATE OF TH	T)
	C#13	IF (3HH (INFAT) GT.J.)) SEGUL JUEAT) = CEGA I (INFA EMOLIS (HEAT) = CEGA I (NEXT) = (NUSE) = (CAS = NUSE))	T) 0nQ0590n
	(4 7	FMGSU(JHERT) = CFCHJ(JNIKT) = (NUSEL + (14XL - NOCF))	T) 0nQ0590n
c		IF (3HH (INFAT) .GT.J.)) >FGPU(JHEAT) = PEFGR IC INFA FMGJU(JHEYT) = PEGHJ(JNÍKT) + (NUSEL + (18KL - NORFC)) BO TU 231 CIRCULATION INDHCED DY SEGMENT BY SPONTH OF SI	7) 0n00590n /2.)) 0n00591n 0n00592n

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	THE ENTIRE SEGMENT WING THE CALINDRICAL BODY SECTION	
223	GAX_MI=((SAMPZEVIMFEDESIN(ADAR(T)))+((AXI-4)=NOSEL)+CHATED)	Un005930
	IF (AALMI .GT. AKLF) BAKL 41 = (SAMPZ VI VF+D+SIN (ADAR(I))).	0005940
,	((AXLE-NOSE_) +GRATE) + ((AXLM1-AALF) +GPATF+0.4)	Un00595n
	GAX_#((GAMP2*VINF*D*51 (ADAR(I))) + ((AXI -NOSFL)*GRATE))	0005960
	IF (AXL.GT.AXLE) GA4L=(344P24V1 NF+D+STI(4)A0(T))+	01005970
	1 ((AXLE-NUSEL) +GRATE) + ((AXL-AXLE) +3RATE+ 1.4)	00005980
	GBU(JNExT)=(GAX[+34x[4])/2.	01005990
	CALL: EURU (JYEXT, ICASE)	0006000
	IF(ICASE.EQ.0160 T) 224	01006010
•	60 10 245	0000020
622	GBIJ (JNE x T) = (1.0	01006030
	GAU(JNEXI) =-GAU(JNEXI)	00006040
:	SIDE FURLE AND YAWING HOMENT CALCULATIONS	
224	SFRAU(JNEXT) = ABS (37) (JNEXT)) * AHOT NE + VC+SERL	00006050
-	IF (3du (INEXT) . GT. 0. 0) SEGHULUNEAT) == CEGA (INEXT)	0006060
,	FMG3U(JNEXT)=SFGBJ(JNEx(T)+(AALM)+(SFGL/2.))	00006070
	125 01 09	00006080
220	IF(JNEXT+31,4)5) 10 222	00000000
:	A BRIVAL PROTECT OF THILLIAN THE CENTURY OF THE CENTURY	
	MODIFIED SHOWTH RATE	
	JNM2=JNEXT-2	Un005100
	IF (ABS (ASEP (JUMS)). ST. NOSEL) OD TO 222'	00006110
	DIFF=Add (GSEP (JHEXT)) = AdS (GSEP (JMAZ))	00005120
	GRA)34=GA-1/01FF	Un006130
	GAX_MI=GHAD34# (4X_M)-4 IS (35EP (UUV2) 1)	00006140
	IF (ABS (SSEP (JNMP)) . 31 . 4KL E) SAKLM) = 0 . 4+37An34+ (AXLM) = ABS (GSED (JNMP)	
	1))	00006160
	IF (AXLM) . IT. AXLF. AV). A 15 (GSEP (JUICZ)) . LT. AYLF) GAXLW] = ((AXLE	00006170
	T-ARS(655FP(J4M2)))+374J74)+((AXLH1-AVLF)+60A734*0.4)	01006180
	GAX_#GHAU 4** (AXI = 435 (35EH (U 4M2)))	00006190
٠,	IF (BBS (GSFP (JVM2)). ST.AKLE) SHKLED, 44GRAD 744 (AKLEAGS (GSED (JV42)))	0006200
	IF (ARL GT. ARLE GAN). ABS (USEP (UNMP)) .; T. ARLF) GARL = ((AYLE-	0000621n
	TARS(GSEP(JMM2)))+548)34)+((&AL-&x_E)+GRAN74+0.4)	0006220
	XPOINT = AA_M1 + (SEG_V2+)	0006230
	- CAL_ X17(H+)+THETAT+ABSEP(UHEXT)+SSEP(UMEYT)+GSEP(UMM2)+XPOTNT+Y+	ZUn00KZ40
	1 • A 2 • A 2 • A 2 • A 2 • A 2 • A 2 • A 2 • A 2 • A 2 • A 2 • A 2 • A 2 • A 2 • A 2 • A 2 • A 2 • A 2 • A 2	0n006250
	RDIST = Simi((Y++2.)+(Z++2.))	00004260
	RCA_ = PUTSI/)	0n00627n
	IF(RCAL.GT.3A4LTM) 7) 1) 526	04004580
	GAX_M1 = SAXLU1 + ((SAMLIM - RCAL)/SAMITH)	00006290
•	ADJUSTING CIRCULATION TO ACCOUNT FOR RANTAL DECAY	
	SAY_ = GAYL # ((GAM_UM - RUAL)/GAMLTM)	01006300
	GAX_M1 = 3AXL41 * C35(A1) *CU5(A2)	00006310
	GAX. = GAXL + COS(A1) +COS(A2)	Un006320
	60 10 225	00006330
822	JNM2=JNEXT=2	00006340
,	CIRCULATION INDICED AT STARET VORTICES HANING REGILLAR GROWTH RATE	0.00/35.
	- GAXLM1=9HATE#{AXL4}-435(GSEP(UNHZ)); - IF(ABS(GSEP(UNHZ)).31.4XL5)3AXL41=0.4467ATE#(AXLM1-xMS(GSEP{UNMZ))	0006350
	1) IF(AX) -4)-51.AxLF.AN)-AHS(GSEP(J1442)). T.AYLF)GAXLW]=((AKLE=	0n006370 0n00638n
	IP (ANIMI+91+AXLE-ANIHMAS (BOEM (BMMI)+AXLE) #GRATE#0.4)	0006390
]#M5(U5E=(JMMZ))}*344;#J+((MXCMI=AXEF)#MAKTE#U.4) - GAX_=GHATF#(AYL=A35("SSFP(JMMZ)))	00000390
	IF(ABS(;SFP(JMM2)), 3T. 1XLEIGAXL=n_4sGQ4FFs(AAL-ABS(cSEP(JNM2)))	0006410
	IF(AUST)SS-P(JUMP/), 34.14LE/JUMALEM, 48M44 F8(MALEMOSCP(JUMP/)); IF(AUST)SS-P(JUMP/), 34.14LE/JUMALEM, 48M44 F8(MALEMOSCP(JUMP/));	0006420
	IABS(GSEP(,INMZ))) = 344 TE) + (AALTAKLE) #GRATERA.A	00006430
	XPOINT = AX_M1 + (5EG_V2+)	0n006440
	DEMANT DE MOUNT DE L'ENGERGET	~ 11 Y Y C 7 7 U

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CALL RY/(H+)-THETAL+45SEP(UNEXI).38=P(UNEVI) POSEP(UNEX).XPOTNIC+450006450 1.41.A2) 0006460 RDIST = SQHF((Y++2.)+(Z++2.)) 0006470 RCAL = PDIST/1 00006480 IF (RCAL,GT. 3A WLIM) 30 In 622 00006490 GAX_ME = SARLAL * (IGAALIA - RUALIZAMITA) 00006500 GAXL = GAXL + ((GAY_E+ - RCAL)/GAYLTM) 00006510 C_X_M1 = GAXL41 + CD=(41) +CUS(42) 00006520 GAX: = GAXL + COS(41) +CUS(AZ) 00006530 GO TU 225 00006540 C COME TO 219 WHEN NO VORTIVES SCHARATE WITHIN BOUNDS OF SEGMENT OF INTEREST. TWO GROWING VORTICES DASS OVER THE FUTIRE SERMENT. C 218 JP1=J+1 00006550 Ich+f=[[828 00 00005560 IF(J1.EQ.2)30 TO 224 00006570 IF()1.6T.2)30 To 23) 0n00658n 229 IF (AXL.GF.NOSFL.AND.AALMI.UE.NUCF_DOOLTO >31 00006590 000066 On SES OF COLLECONTONIAN TE SEGMENT ENTIRFLY DW NOWE GBU(J1)=0.0 00006510 60 IU 233 00006620 CIRCULATION INDUCED BY SECURD VOWIEW WHEN SEGMENT STARTS ON NOSE 232 GAX_M1=0.0 0n00663n GNOSEL=GAMP2+VINF+D+SIN(ADAH(I)) 01006641 (fatassettasse))+(((I)saca) wizettasseas) # [xab 0n006650 IF(AXL+GT.AXLE)GAXL=(344P24VINF+D+STM(ADAD(T)))+((AYLE-NOSE))+ 0n006660 IGRATE) + ((AXL-AXLE) *9.4+GRATE) 00006670 GBH(J1) = (GAXL+GNOSE_9/2. 0006680 CAL_ FURDIJI+TCASE) 00006690 IF(ICASE.EQ.O) GO TO 233 00006700 00006710 249 GBH(J1)==GBJ(j1) SIDE FORCE AND YAWING MUMENT CALCULATIONS 233 SFG3U(J1)=A3S(GHU(J1))+RHOINF+YC+(AYL+N)SFL) 00006720 IF (360()1).3T.0.0) 37640(01) == SFGG ((1) 00004730 FMG3U(J))=SFG3U(J)) P(NOSEL+((AX)=NOCEL)/2)) 01005740 80 IN 75H 00006750 CIRCULATION INDUCED BY SECUND VORTEY WHEN ENTIRE REGMENT IS DV CYLINORICAL PARTIDA UF HODY 231 GAX_Ml=((GAYP>*VINF+D*SIN(ADAC(T))).((AX(+1-NOSEL)*GRATE)) 0n00676n IF (AXEM1.GT.AXEE) SAXEMI = (GAMP2#YTNF&DAGTN/AMAR(I))). 00004770 1 ((ARLE-NOSE_) +GRATE) + ((AALM) +AAL) +BOATE+1 4) 00006780 GAY_F((GA 4P2+VINF+D+SI ((A)AA((I)))+((AXL-NASFL)+GRATE)) 04006790 IF (4XL-GT.AXL=)GAXL=(344P2*VINF+7#STN(A7A0(T)))+ 0006800 1 ((AXLE-NUREL) +GRATE) + ((AXL-AALE) +3RATE*1.4) 00006810 0606820 236 GBU(J1)=(3AXL+64X_41)/2. 0n00683n CAL_ EURO (J1+TCASE) IF (ICASE.EU. 0) 60 TU 200 00006840 SO 10 251 00006850 623 GBU(J1)=0.0 00006960 251 GBU(J1)==58J(J1) 00006870 SIDE FORCE AND YANTING ADMENT CALCULATIONS 250 SEGBU(U1)=ABS(GRU(U1))+RHUINF**C+SEGE 00006880 IF(3dU()1).3T.0.0)SFB3U()1)≈=SFG4(()1) Un004898 FMG3U(J1) = SFG3U(J1) = (4x1,M1+(SE51 /2+1) 00005900 60 LO 450 00006910 230 IF(J1.6T.4)30 To 234 0006920

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	CIRCULATION INDUCED ST INITIAL TO TREET VORTICES HE	•
:	CTROULATION INDUCED BY INTITIAL TOT STREET VORTICES HE	AVING MODIFTED
;	GROWTH RATE	_
	JIMS#J1-2	0,006930
	DIFFFARS (GSEP (J1)) - 483 (GSEP (J1M2))	0006940
	BRAD34=34~1/DIFF	00006950
	GAX_M1=GRAD34+(AX_M1-4+5(55FP(J1M7)))	0006960
	IF (ABS (GSEP (JIMP)). 3T. 4XLE) GAXLM1 = 0.4 +GP4n34 + (AXLM1-	
	1))	00006980
	IF (AXLM1.GT.AXLE.AV).A3S(3SEP(J1M2)).LT.AYLE) GAXLM1.	
	1-AB5(GSEP(J1M7)))#GRADR4)+((AXL41-4xLF)#GDAD34#0.4)	0007000
	GAXLEGRAD34+(AXL-ABS(34EP(U)MZ)))	00007010
	IF (ABS (GSEP (JIMZ)) . GT . AXLE) GAXLED. 4-694774 P (AXL-ARS)	
	IF (AXL. GT. AXLE. AND. ABB (GSEP (JIMP)) . I T. AYL F) GAXLE ((AY	
	1-A85(GSEP(J1M2)))+GRADU+)+((AXL-AXLF)+GRAN34*0.4)	0007040
	XPOINT = AXLM1 + (SEG_V2.)	0007050
	CALLI XYZ (H.) THETAI . A SEP (U1) . GREDI (11) . SREP (U1MP) . XD	DINT+Y+7+41.4200007000
	1)	00007070
	RDIST=SQR(((Y**?*)+(2**?*))	0,007080
	RCALE # RUIST/7	0,007090
	IF (RCAL.GT. 3AMLIM) S) 17 623	01007100
C		0.000000
	GAXLM1 = SAKLW1 + ((GAML14 - RCAL)/GAMLIM)	0007110
	BAXLI = GAXL + ((GAM_E4 - RCAL)/GAMLIM)	00007120
	BAXLM1 = GAXLW1 + COP(A1) + COS(AP)	0007130
	GAXL = GAYL + COS(41) +COS(A2)	0007140
	80 TO 236	0n007150
_	234 J1M2=J1-2	0007160
C		ATMS MONTAN I
Ç		0007170
	GAXLM1=3HATE+(AKLM1-AM-(GSEP(J1M2)))	
	IF (ABS (GSEP (J)MP)). 3T. AXLE) SAXLM1 =0.4894ATE# (AXLM1-A	0n00719n
	1) IF(AXLM1.GT.AXLE.AV).445(35EP(J1M2)).ET.AVLE)GAXLMIR	•
	1A85(6SEP(J142)))+344TE9+((AXL41-AXLF)+67ATE+0.4)	0007210
	GAXLEGRATE*(AxL=AdS(G>EP(J142)))	0007220
	IF(ABS(GSEP(J)M2)).37.44LE)GAKLEO.4+GRATF+(AXL-ABS(A	
	IF (AXL. ST. AXL T. AND. ASS (SSEP (JIMP)) . T. A (F) GAXL= ((AY	
	TARS (GSEP (J142))) + GRATE) + ((AXL-AXLE) + GRATE+0.4)	01007250
	XPOINT = AX_M: + (SEG_V2.)	0ñ007260
	CALLIXYZ (H+)+THETAI+#35EP(U))+GGF>(())+39EP(U1M2)+XD	0757000054.1447.4410
,	1)	0007280
	RN15T=S;HT((Y++2+)+(L++2+))	0n007290
	RCA = RUTST/7	0n00730n
	IFIRCAL.GT.3AMLIM)37 TO 623	0n007310
C		
	BAXLM1 = GAXEW1 + ((GAMLIM - RCAL)/CAMETM)	0007320
	BAX_I = GAXL + ((GAY_E4 - RUAL)/GAYLTM)	0007330
	GAX_MI = GAXLHI + COS(AI) + COS(AP)	0007340
	GAX_ = SAAL + COS(A1) +COS(42)	0007350
	GO TO 236	00007360
	228 CONTINUE	0007370
	221 gF(<)=0.0	0n007380 0n00739n
_	FMT(K)=0+0 C ZEDITACV CHICLIBLEINTAC OFF CHECK	VNUV / 370
C		0007400
	YAWL-1=T-JAWAY	0007410
	SFPC(JI)=0.0	0007420
	FMGPC(JT)=0.0 SFPSV(JT)=0.0	00007430
	3FF3F[4] / #V • V	5000,450

		TELL STORY COUNTY	
		, EDV-	
		F4G25V(JT)=0.1	0n007440
C		SUM CONTRIBUTIONS TO SIDE FORCE AND YAMTHE MUMENT ON EACH SEGMENT	
		SF(<)#SF(<)+SFPC(Jf)+SFPSV(Jf)+SFR3UTS(Jf)+SFBUAS(If)+SFBU(If)	Un007450
		FMT(K)=FMT(K)+FMGPC(JT)+FMGPSV(IT)+FMGRHT(JT)+FMB IAC(JT)	0n007460
	•	I+FMSBU(JT)	00007470
		CONTINUE	0007480
C	- 2 -	CALCULATE SEGMENT CENTER OF PHESSIRE	
		XARHEAHS(FMT(4))/AHS(SF(K))	0007490
		YM04(K) =SF(<) +X4R4	0007500
C		GO TO NEXT SEGMENT AND REPEAT CALCULATIONS	•
•	200	CONTINUE	00007510
	200	15F=U.U	0007520
		13F-000	0007530
C		SUR SIDE FORCE AND YAWING MOMENT CONTRIBUTIONS FROM ALL SERVENTS	01100100
C		00 415 <=1+42	00007540
			01007550
		TSF=TSF+SF(<)	0007560
	• • •	TYM9H=FYM9M+Y (04 (<)	
_		CONTINUE	0007570
C		GO TO SA IF ISPLATED SHOT	
		IF (1) CUVF. E3.1) 30 17 39	0007580
		×AP L=1×AML	
		DO 350 K=1+JMAX	0007590
		IF (ABS (GSEP (K)) LEGARS (EHOUYL)) OF TO 350	00007600
•		JMAXI=K-I	
	,	GO 10 352	0007620
	350	CONTINUE	00007630
	352	NFF1=0	00007640
	•	TSF=TSF.SF(<) TYMOH=IYMOM+Y 40M(<) CONTINUE GO TU 54 IF ISOLA(E) 300Y IF(LUCUMF.EQ.1) 9U TO 54 JMAXI=JMAX DO 350 K=1*JMAX IF(ABS(GSEP(K))*LE**ABS(EHOUYL)) 90 TO 350 JMAXI=K-1 GO TU 357 CONTINUE MFF1=0 JMAX=JMAX)	_
		FNF1(I)=0.0	0ñ00765n
	•	SRO_d(1)=0.0	0n007660
C		CAL FINCAL TO CARRY DUT VURTEX/FIN INTERACTION CALCULATIONS	
	351	CAL FINCAL (JUAX+36 45 / (1) + AFH+ YFD+ ZFH+ XDMAX+ XF+ ZF+4A++ ZF+LAM+	05007670
	_ •	1GSE2[{]}+GSEP7(})+H+E+P1+D+VINFA+SRFFT+RHAINF+GSEP(})+RNFY+TSTO>+	0007680
	:	PRNF.HYCP+ROLM)	0n007690
		IF([STUP_EQ.1)[SKIP(])=[0007700
C	*	IF ISTUDE 1 A VORTER PASSES WITHT - 1/4 ANDV PADIJS OF FINA	· .
Ċ		DISCUNTINUE CALCULATIONS + SU TO NEXT ANGLE OF ATTACK	
•		IF([STOP.FU.1)G0 TO 5=	00007710
		SRO_M(I)=SROLW(I)+RJLM	0007720
C		SUM SIDE FORCE AND YANING MOMENT	
		TSF=T-F+RVFY	00007730
		TYNDMETYMOM+((ARS(ERO)YL)+(ABS(YFMAY-XF)/>.)) +RVFY)	0007740
۴		TE: AMAEU.0.0 NEED = 1	00007750
		IF (_AM.EQ.0.0) FNF1(I) =4 NF	0007760
		NORA=NOHA+1	0007770
C		GO TO SA WHEN CONTRIBUTIONS FROM ALE FING HAVE REEN CALCULATED	
•		IF (VORA, GT. NLAM) GD TO 38	04007780
		IF (NORA, GT. NLAM) GD TO 38 LAMENA(NORA)	0007790
	-	[AM]=[AM	0007800
		LAM*LAM/57.29577	0007810
c		CALCULATE CONDITNATES OF FIR RUNT CHURN LEADING EDGE	AUDALDED :
_		ARDEAR	0007820
			0007830
		YFR==1.*(0/2.)*SIV(_N*)	
		ZFR=(1//2.) *CUR([A4)	0007840
_		60 (U 351	0n00785n
С		CALCULATE FREE STREAM DIMANIC POFES OF	0.00000
_	58	Q=,5*RHOINF*(VINF**?.)	0007869
C		CALCULATE SIDE FURCE AND YAWING MOMENT CORFFICIENTS	. 3
			4

	AMAZIA-TOSAL MADASI	
	CY(1) = TSF/(1 + SRFF)	0,007870
	CETA(I)=TYMOM/(Q+SREF+O)	00007980
C	TRANSFER OF YAMING MOMENT	
,	CETAMC(I)=((CTT4(I)/CY(I))-(XMC/D))+CY(I)	0007990
	52 CONTINUE	00007900
	IF(IDCONF,EQ.0)GO TO 23	0007910
C	PRINT BODY PLIS TAILI DUTPUT	
	IF(VFF1.NE.O) #RITE(5+9) XMC	0007920
	8 FORMAT(3X.15H&NGLE OF ATTAUK.AX.PHCY.6X.6HCFTAMC.7X.9HROLL WOV	•
	Z4X+12HNRNHAL: FORCE+/+	
	36x±9H(DEGREES) +14x + 3HCG=+F5,2+2HFT+Gx+7+(FT-L8) +4x+	1 .
	416H(FIN NO. 1 (LB)))	1
•	IF(MFF1.EQ.O) WRITE(5+1n) XML	00007970
	10 FORMAT(3X,15HANGLE OF ATTACK+4A,2HCY+6X+6HCETAMC+7X,9HHOLL MOM	
-	# 6x.9H(DEGREES) .14x.3+CG=.F5.2.2MFIT.5x.7H(FT-LB))	
*	DO 313 I=1.NA7A	00000000
	IF(ISKIP(1).Nr.n)30 TJ 313	00000010
•	IF (NFF1.NE.U) ARITE(5++) ADAU(1) +CY(1) +CETAHC(1) +SHOLW(1) +FNF1(1)	0000020
٠	9 FORMATITX.F5.2.6X.F7.3.5X.F7.3.6X.F7.3.7X.FA.3)	00000030
	IF(NFF1.E3.0) #RITE(5+1) AOAD(I).CY(+).CETAMC(I).SRO(M(I)	00008040
•	11 FORMAT(7X,F6,2,6X,F7,3,5X,F7,3,6X,F7,3)	00000000
	313 CONTINUE	00008060
	60 TO 24	
c	PRINT ISCIATED RODY DUPPUT	00000070
C		0.00000
	23 WRITE (6.25) XM^	0000000
	25 FORMATISX. 15HANGLE OF ATTACK. AA. 24CY. 64. 64CETAMC. /.	
	26x,9H(DEGHEES) +14x,3HCG=+F5.2+CHFT)	0.000110
	DO 26 I=1.N404	00000110
	WRITE(6,27) AOAD(I), CY(I), CETAMC(T)	00008120
	27 FORMAT(7X,F6,2,6X,F7,3,5X,F7,3)	00000130
	26 CONTINUE	0000A140
_	IF (10P1.NE.1) 30 TO 24	00005:50
C	IF IOPT=1 SCALE ISOLATED BODY OUTPHT FOR NOSE FINENESS RATTO AV	5
C	BLUNTNESS RATIO EFFECTS	
	CALL! OPT1 (FSMN+NOSE_H)+ HRN+XMC+CY(1)+CETA(1)+CETAMC(1)+	00008160
	2IPASS. VAUA)	00008161
	IF (1PASS-EU-DIGD TO 24	00008170
	WRITE(6.800)	0000B180
	BOD FORMAT(1X.12HDICKS OPTION)	
	WRITE (6,25) XM^	0008800
	DO 801 [=1. VADA	00008210
	WRITE(6.27) 40AD(I) + CY(I) + CLTAMC(T)	0000A220
	BOI CONTINUE	00008230
_	24 READ(5+4) INUN	0n00827n
C	CHECK TO SEE IF ANOTHER RUN IS TO BE MADE	
	IF (IRUN. En. 1) 30 TO 41	00008280
	CALL EXIT	00008290
	END	000A300

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	SUPPORTINE RALIANT THE METAL SALE SALE SALE SALES SALE	0000310
C	***************************************	*****
Č	SUBROUTINE AYZ CALCULATES COORDINATES OF POINTS ALONG VONT	Fy
Č	GROWTH TRAJECTORY	
Č		
•	IF(ABS(AJ).3T.A9S(XJ)) NO TU 100	0n00#32n
C		^
Č	NORMAL STREET VOHTER	
. •	PI =ATAN(((4/2.)-(()/2.)+COS(THFT&I)))/(ARS(XJ)-ARS(XJM2))) 0600R33n
•	CERAR (ABS(XJ) -X)/COS(PI)	0n00m340
	ACBAH = SORT(((H/2.)-((D/2.)+Cos(THFT4T)))++2)+	0ñ00a350
	(S##((SMLA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZEA-(LA)ZE	00008360
	((19) PATP(X - ((ABG(XJ) - (-5/1)=Z	0600A370
	101 DELTA = ATANIJSARFILLIANZ. 1+509111(4/2.) ++2.1+(10/2.) ++2.11	1.42. 00008380
	1-(1/2.)**2.))-(1)/2.)*SIN(THETAT)))/ACRAD)	00008390
	Y = ((ACBAR-CEBAR) + TANIDELTA)) + (17/2.) +COR(THETAT)	00008400
	GO TO 102	00000410
C		
~	VORTEX FURCED TO SEPARATE AT THE BASE OF THE BODY	•
•	(SPLX) = ATAN(((H/2.)-(()/2.)+())) ((HFTAT))) /(AR(AJ)=AR(XJ42)	11 00008420
	CEBAR = (AdS(A))-X)/205(PI)	00008430
	ACBAR =50PT((((4/2.)-((0/2.)*CUS(THETAT)))*#2)+	06006440
	1 (S** ((SM:X) ZEA - (LA) ZEA -	00008450
	Z= (H/2,)-(LA)(A)(X)(X)(LA)(A)(X)	0000000
	60 TO 101	00008470
	102 RETURN	00008480
	ENO	00008490
	Plant.	

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SUBRUUTINE EORO(INT+IEn)	00009500
	. ⊕ ₩
SUBGOUTINE EDGO DETERMINES IF A VORTER TO NUMBERED EVEN OR ODD.	•
THIS DETERMINES THE SIGN APPLIED TO THE CERCULATION	
Tarana T	0n00a510
INPl=INT+1	0n00a52o
INP102=InD1/2	00008530
IFnei	00008540
IF (INPINZ.GT.: NTDZ) IE J=0	0100R550
ODD IEU=0	00008560
EVEN IEO=1	00008570
RELJRN	00008580
END	00008590

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•		
	THIS PAGE IS BEST QUALITY FRAUTI	CARLLE
Etuca I	TAGE IS BEST QUALITY	
FINCAL	THIS PAGE TO THE TAXABLE THE PAGE TO THE P	•
SUBSIDITING STUCAL LIMAT GAME	THIS PAGE IS DAMP TO THE PROPERTY OF THE PAGE OF THE P	0000000
SUNTOUTINE FINCALL JANA TOWN	STANT ACTIVES TO SECONDAL SECONDAL SECTION	
1025-10025-544-54-110101010101	A.SREF. AMAINF. GCEP. RNFY. ICTOP.	01000610
PRNF + RYCP + ROLM)		0000000
REALI LAM		0n00A630
DIMENSION GAMEY(1)+36:PT(1)).OSEP7()).GSFP()).X(10).v(!0).Z(10).	0000000
1VNT(10) .VT(10) .AU405(10) .V	N4MH (20) +FN (20)	01008650
DIMENSION YCP (20)		0n00A660
	LS THE NOTHAL FARCE INDUCED ON FINS BY	
SHED VORTICES IN THE HODY	LEE STOE WAKE	•
***********	*********	•
JSTART=.JMAX-1		Un008670
DO 53 JEJSTART+ 1MA×		00008680
SHED VORTEX STRENGTHI	•	
GAM=GAMSV(J)		0n008690
CALCULATION OF CURRILINATES	ON FIN LEADING ENGE WHERE CA_CULATIONS	
ARE TO BE MADE	,	
X(1)=XF9	· · · · · · · · · · · · · · · · · · ·	00008700
Y(1)=YFR	/	00000710
Z(1)=ZF0		0n008720
FLES=(XFMAX-XF)/(ZF4AX-ZF)		00008730
DEL Z=(ZFMAX-ZF)/10.		00008740
DO 51 I=1.10		00008750
IF(1.67.1)60 to 55		00000760
X(1)=FLFS+()E_Z/2.)+X(1)		00008770
Z(1)=Z(1)+()E Z/2+)+CJS(LA)	M)	00000780
Y(1)=Y(1)-()E_Z/2.) +51 +(LA		0000A700
GO TU 57		UNDORBOO
56 K=1-1		00008910
X(1) =FLES+UEL7+y(4)		01008820
Z(1)=Z(K)+DEL7*CO5(_A*)		0000830
Y(T)=Y(K)-DEL7#514(_A4)		00008840
	UF VUNTER REPARATION TO PAINT ON FIN	
57 DELX=ABS(X(I)+GSEPT(J))		00000850
DEFINITION OF VORTEK _ATER	AL DIED AFFEUT	
IF (3AM. GT. O. AND. J. LE. 2) Y		01008860
IF (SAM.GT.0.0.AND. 1.GT.2) Y		00008870
		0000880
IF (GAM.LT.0.1.AN). JE.2)		00008990
IF (SAM.LT.U.O.AND.J.ST.2)		0.008900
	AHI.UH.J.FO.JMAX)YVCL=GCEDZ(J)	00008910
A1 = (ABS(Z(I) -)E(X*T4N(E)))		0100A920
81=485(YVCL+Y(I))	- C - 2 1 - 1	00000930
ANG_E=ATAN(A1/91)		00008940
BRAR=DELX/COS(E)		00000950
DBBAR=(APS(DE_X+TrN(F)=Z(I)	1114644451	00008960
	,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,	00000070
BRAR=BBAR=DRBAR Zadj=Brake>In(E)	•	00008980
PHT1=AGGLE	•	00008990
	A CORPITÓ POTNT ON FIN MENSURED NIONG	OUGGESSO
A LINE PERPENDICULAR TO THE	E ANALEX CINÉ	0-00-000
67 RI=(ARS(Z(I)=DELX*TAN(E)))	-CO21F1/21/(PH[1)	0000000
410×41/(0/2.)		00009010
	A RODA SAUTHE OF BOINT ON EIN	. '
DISCONTINUE CALCULATIONS		
[F/PIN-18.0.25150 TT 21	*•	00000020
AEFOCITA LADROEL ALIBORAL	JI FIN AY VOATEY	
411#9#4\(2.004[en])		00009030
COMPONENTS OF VELOCITY		

```
THIS PAGE IS BEST QUALITY PRACTILIZED
   VY1=VTI+SIN(P-II)
                                                                          00000000
   VZ1=VT1+CoS(PHI1) *COS(E)
                                                                          00009050
                                       TROW OOFY PURMISHED TO DOG
   IF (ZADJ.LT.Z(T))GD TO 86
                                                                          00009060
   IF (YVCL.LT.Y(T))GO TO HT
                                                                          00009070
                                                                          0009080
   VY1==1.+VY1
                                                                          00009090
   60 TO 69
                                                                          00009100
97 VY1=-1.+VY1
                                                                           00000110
   VZ1=-1. - VZ1
                                                                           0000120
   GO TO 64
                                                                           00009130
86 IF (YVCL.LT.Y(T)) VZ1 =-1. + VZ1
69 YYN1=VY1+CU5([A4) .
                                                                           00009140
                                                                           00009150
   VZN1=VZ1=SIN( AM)
   NORMAL COMPONENT OF VELOCITY INDUCED ON FIN BY WORTEX
                                                                          00009160
   VN1=VYN1+JZV1
   AZ=ABS(Z(I)-DELX*TAN(E))
                                                                          00009170
                                                                          00009180
   B2=ABS(YVCL-Y(I))
   ANGLEZ=ATAN(AZ/RZ)
                                                                           00009190
                                                                           00009200
   ZADJ2=DELx =TAy(F)
                                                                           00009210
   PHI2=ANGLES
                                                                           0009220
70 RZ=(ARS(Z(I)-)ELX#TAN(F)))/SIN(PHT?)
                                                                           06560000
   IF (YVCL.GT.Y(T).AND.ZA)JZ.GT.Z(T)) SO TO HA
                                                                           0009240
   IF (YVCL.LT.Y(T).AND.ZA)JZ.OT.Z(T))30 TO RO
                                                                           00009250
   IF(YVCL.GT.Y(T).AVD.ZADUZ.LT.Z(T)) GO 'TO GO
   IF ( YVCL.LT. Y ( T ) . A NO. 7 A ) J2. LT. Z ( T ) ) 30 TO 91
                                                                           00009260
   DEFINITION OF EQUIVALIBLE VURIER STRENGTH
                                                                           00009270
gg GAM2=VN1+(2.+0H1+42)/(COS(PH12)+SIN(EAM)-SIN(PH12)+CUS(_AM)1
                                                                           00009280
   GO TO 13
89 GAM2=-1. *VN1*(2. *PHI* P)/(5]N(PHIP) +COS(LAM) +COS(PHIP) *SIN((AN))
                                                                           00009290
   GO TO 73
                                                                           00009300
                                                                           01009310
   GAMP=VN1=(2.=PH;*RZ)/(S[N(PHIZ)*CDS(LAM)+COS(PHIZ)*CIN(_AM))
                                                                           00009320
   30 tu 73
91 GAM2=VN1*(2.*oH1*32)/(SIN(PHIZ)*C)S(LAM)=COS(PHIZ)*CIN(_AM))
                                                                           00009330
   LOCATION OF IMAGE VORTEX
73 F#SQRT(((ABS(YVCL)) ##2.)+(UELX*TAN(F)) ##7.)
                                                                           00009340
                                                                           00009350
   GI=((D/2.) ++2.)/F
                                                                           00009360
   THETARATANI (ARS (YVC_D) / (DELX*TAN(F)))
   IF (3AH2.Gr.n.n) THETA == 1. +THETA
                                                                           00000370
   YI=31+5TN(THETA)
                                                                           01009380
                                                                           00009390
   ZI=31 +CAS (THETA)
                                                                           01009400
   RI=SURT(((A3S(Y(I)-YI))+#2.)*(A95(7(I)-71))+#2.)
   GAMI=-1. SAMZ
                                                                           00009410
   CALCULATE VELOCITY INDICED AT POINT ON FIN AY IMAGE VORTEX
                                                                           00009420
   VTI=GAMI/(2. # OHT#RI)
                                                                           00009430
   M2I=ARS(2(I)-7I)
                                                                           00009440
   821 #ABS(Y1-Y(T))
                                                                           00009450
   ANGLEI#ATAN(API/H?I)
                                                                           00009460
   PHIZI=ANGLEI
   VYI=VT[+SIN(P+171)
                                                                           01009470
   VZI=VTI+COS(P-I2I)
                                                                           00009480
                                                                           00009490
   IF(ZI.LT.7(I))60 10 92
                                                                           00009500
   IF(YI.LT.Y(I);Gn TO 93
                                                                           00009510
   VYI=-1.+VYI
   GO TO 76
                                                                           00009520
                                                                           00009530
IYV#.f~1.#VYI
                                                                           00009540
   VZ1==1.#471
                                                                           01009550
   GO TO 75
92 IF (YI.LT.Y(I); VZI==1. "VZI
                                                                           00009560
                                                                           00009570
76 WYNI#VYI#COS((A4)
```

FINCAL

		VZNL=VZI*SIV(Au)	00009580
C		BEANT YE WIR NO INTO TA MEDITONI VILLEN TO THENCHED JAMBON	UNQU43011
Č		VORTEX	
•			
		ANI=AANI+ASAI	00009590
_		RC=SURT(A9S(Y(1)) ++?.+18S(Z(1)) ++2.1	0000000
C		CALCULATION OF NORMAL COMPONENT OF OFLICTLY INDICED AT DUINT	
C		ON FIN RY CENTHAL VORIEX	•
		VNC=GAM2/(2.9>HI93C)	00009610
C		SUMMATION OF MORMAL VELOCITY COMPONENTS FOR ALL SEGMENTS	
-		VNT (I) = VNI + VN	0009620
	51	CONTINUE	00009630
		VT())=0.0	
		D0 32 I=1.10	00000640
			00009550
		YT()) = YT(J) * YYT([)	00009660
	50	CONTINUE	0009670
_		00 33 1=1.10	00009680
C		EFFECTIVE ANGLE OF ATTACK INDUCTO AT POTHE ON FIN	
		AOA)S(I) = ATAN (AAS (V "T (T)) / VINFA)	01009690
		IF(VNE(F).6F.4.4) 4 1475(I) x=1.047475(F)	00000700
	A3	CONTINUE	0n00971n
		\$\chince{0.0}\$	0n00972n
		SADY=0.0	00000730
		DO 44 I=1.10	00009740
		IF([.EW.1)YCPT=n/2.+DEL2/2.	04009750
		IF(1.57.1)YCPT=YCP1.DELZ	00009760
		SYADY=ADANS(I)+YC2(+DilZ+SYADY	00009770
		SADY=AUAUS(1)+DFLY+SADY	
	-	CONTINUE	00009780
С	77	FIN SPANNISE CENTED OF PRESSURE	00009790
C			
С		**CP(J) ************************************	0000000
L		AVENAGE VELOCITY 1 DUCED AT FIN FEATING ENGE	
		VMR4H(J) = AUS(VT(J) / 1) .))	00009910
		AIN TATAM (U) NAI VEA)	00009920
		*FL4=SURT((VINFA==>,) + (VNBA+(J) ++>,1)	0000930
		AREZ. # (ZF4AX-7F) #42./SHEF	00009840
		CNA=PHI = AR/2.	0n00985n
		3=0*2e440[N±e(Atf4+65*)	0400960
C		NORMAL FURCE INDUCED: DN FIN BY A VOITEX	
		FN(J)#CNA#AIN;#g#59EF	00000070
		AIND#4110+57.59	00009880
		IF(vT(J).LT.0.0)Fv(J)=-1.*F4(J)	00009990
C		LOOP AND CALCILLATE NORMAL BONCE FUDICED BY ALL STHES VORTICES IN	1
Ċ		MAY E	
	53	CONTINUE	0000000
	•	RNF = U. U	00009910
C		REDULIANT FIN MANA I TOUCE	. 00003210
•		DO 54 ImJSTART JMAX	0:00000
			00009920
		Angendre or atty	00009930
	74	CONTI TUE	00009940
		RNFY=RNF®CO3(_A4)	00009950
		RNF (=HNF#SI V(_AH)	00009960
_		RM#0.0	00009970
C.		CALCULATE ROLLING MOMENT	
		DO 95 I=JSTART, MAX	00009980
		RM=RM+YCP(1) +FN(1)	00009990
	85	CONTINUE	00010000
		RYCP#ABS (RM) /ABS (RVFD	00010010
		BUF AE-1 . BULL SAGE	0010020
		RNF=RNF+FN(I) CONTITUE RNFY=RNF+COS(_AM) RNFZ=RNF+SIN(_AM) RM=0.0 CALCULATE ROLLING MOMENT DO 95 I=USTART, IMAX RM=RM+YCP(I)+FN(I) CONTINUE RYCP=ABS(RM)/ABS(HYF) ROLM=-1.*RNF*FYCP	

75

GO TO 23 21 ISTOP=1 23 RETJRN END 0n010030 0n010040 0n010050 0n01006n C

C

```
SURROUTINE OPTI (FOUNDAMENDO BRNO A ICOCYOCETA CETA 4COTPASSO VADA)
                                                                           00010070
  DIMENSION FRK (6.4). TMACH(6). IFH(4). THR(5). HRK2(6.5).
                                                                           On010080
 28RK3(6+5)+H4K4(6+5)+CY(1)+CET4(1)+CFTAMC(1)
                                                                           00010090
  SUBJOUTINE OPTI SCALES ISOLATED ADDY SIDE FORCE AND YAMING
  MOMENT FOR FINENESS RATIO AND BUINTHESS RATIO EFFECTS
  DATA THACH/0.5+0.5+0.1+0.4+0.9+1.1/
                                                                           00010100
  DATA TF4/2.0+3-0+3-789.4-0/
                                                                           00010110
  DATA FHY/0.267.0.555.1.081.1.027.0.403.0.089.
                                                                           00010120
            0.939.0.799.1.339.1.429.0.373.0.180.
                                                                           00010130
                                                                           0n01n14n
            1.000-1.000-1.000-1.000-1.000-1.000-
            1.014.0.457.7.406.0.714.1.269.1.289/
                                                                           00010150
  DATA THU/0.0+0.5+10.0+20.0+50.0/
                                                                           00010160
  DATA HK42/1.010.1.010.1.000.1.000.1.000.1.000.
                                                                           00010170
                                                                           0n01n18n
             1.000.1.000.1.000.1.000.1.000.1.000.
                                                                   PRACTICABLE
             0.130.0.224+0.234+0.343.0.222.0.250+
                                                                           0n01019n
             3.241.2.134.2.194.3.257.2.435.2.875.
                                                                           00010200
                                                                           01010210
             1.000.0.776.1.114.1.547.0.222.2.260/
  DATA AR<3/1.000.1.000.1.000.1.000.1.000.1.000.
                                                                           02201040
                                                                           00010230
             1.000.1.0001.000.1.000.1.000.1.000.
                                                                THIS PAGE IS BEST QUALITY F
FROM JUFY FUGALSHED TO DDG
             0.703.0.495.0.940.2.440.0.720.1.647.
                                                                           00010240
             0.736.U.522+1.450.2.Unn.2.920.1.778.
                                                                           00010250
             0.796.0.431.0.255.0.221.1:000.0.774/
                                                                           00010260
  DATA RH<4/1.unn.1.030-1.000.1.unn.1.000.1.000.
                                                                           00010270
                                                                           0n01n28n
             1.0n0,1.0ju-1.0au.t.unn.1.0n0,1_0n0.
                                                                           Un010290
             0.477.0.575.0.600.3.440.1.0A2.0.592.
             0.477.4.545.4.613.2.320.4.212.0.170.
                                                                           00010300
             0.295.0.441.0.700.3.440.1.412.0.376/
                                                                           0.010310
  IF (FSMM.L.T. 0. F. OH. F. FAN. GT. 1. 1) on TO 1
                                                                           00010320
                                                                           00010330
  18 (FMN.LT.2.0.04.FAV.55.4.0160 to 1
                                                                           00010340
  1F (3MN-3T.50.0)50 10 1
                                                                           0n01n35n
  IPASS=1
                                                                           00010360
  F+f=I 5 00
                                                                           0n01n370
  1 + 1 = L
                                                                           0n01n38n
  IF (FAN. GE. TFH (I) . 4 4) . FH V. LE. IFH ( I) ) CO TO 2
                                                                           00010390
S CONTINUE
                                                                          00010400
3 IFP=I
                                                                           Ong1041n
  IFP1=J
                                                                           00010420
  DO 4 1=1+5
                                                                          0n01043n
  J=[+1
                                                                          00010440
  IF (FSH4. GF. TMACH (1) . A NI) . FSM4. LE . THACH (11) RO TO 5
                                                                          0n01045n
4. CONTINUE
                                                                          00010460
5 IM=1
                                                                          0n010470
                                                                          0n01n48n
  IM1 = J
  RATIU=(TMACH(TM)-=54N)/(TMACH(IM)-TMACH(TMI))
                                                                          00010490
  Fl=FHK(IM+IFH)-(H4TI)*(FHK(IM+IFD)-FRK(I41+IFR)))
                                                                          0n01050n
  F2=FRK([M+[FH])=(RAT])+(FRK([M+TFR])=FRK([M+[FR])+)
                                                                          00010510
  FRK1=F1-(F1-F2) + ((TFR([FH)-FHN))(TFQ([FR)_TFR([FH1)])
                                                                          00010520
  IF(3KN.LE.5.0)Gn T7 >
                                                                          00010530
  DO / 1=2.4
                                                                          0n010540
  J=1+1
                                                                          00010550
  IF (3KN-SE. [4K(I) - AV) - 3RN-LE. [8K( i) ) an In a
                                                                          00010560
7 CONTINUE
                                                                          00010576
8 18R=I
                                                                          00010580
  IBR1=J
                                                                          00010590
  F1=3HK3(IM, IBR) - (RATI) = (BRK3(IM, IRR) + BRK3(IM1, IRR));
                                                                          00010600
```

```
00010610
   ((((PRPI-1M1)EMPR-((OPT-M1)EMP)+(PRT)+(IPRI-WI)EMPRES
                                                                         00010620
    FImFL-(F1-F2)+((T3R(J3R))-HHV)/(THR(THR)-TBR(18H1));
                                                                         00010630
    IF (FRN.GE.3.0. AND. FRN.LE. 4.0) GU TO 10
    61=8RK2(I4+IBR)=(RATI)=(BRK2(IM+I3R)=RK2(I41+IAR));
                                                                         00010640
    62=3RK2([4+[83])=(R4T10*(8HK2([4+[40])=4PF2([4]+[4R])))
                                                                         00010650
                                                                         00010660
    RATIO1=(2.0-FaN)/(2.0-3.0)
                                                                         00010670
    BO TU 11
10_61=3RK4(14+183)=(44T1)+(84K4(1M+13R)-8844(141+19R)))
                                                                         00010680
                                                                         0n010690
    82=3RK4(I4.18a1)-(HAT10+(HK4(IM.THo))-ARK4(IM1.IRRT)))
                                                                         00010700
    RATIO1=(4.0-FRN)/(4.0-3.0)
                                                                         00010710
 11 81=31-(G1-G2) = ((T3R(13R)-9H4)/(T93(T99)-T9R(IBA))))
                                                                         00010720
    BRKI=GI-(SI-FY) -HATIOL
                                                                         00010730
    51 01 08
                                                                         00010740
  9 BRK [=1.4
                                                                         00010750
 12 DO 13 I=1.NAU4
                                                                         0n010760
    CY(I)=CY(I) +FRK[+3R(I
                                                                         00010770
    CETA(I)=CFTA(I) +FRKI+3RKI
                                                                         00010780
    CETAMC(I)=((CETA(I)/CY(I))-(X4C/D))+CY(T)
                                                                         00010790
 13 CONTINUE
                                                                         00010800
    60 10 14
                                                                         00010810
  1 IPASS=0
                                                                         00010820
 14 RETJRN
                                                                         00010830
    END
```

THIS PADE IS REST A TO A CARLIDATION THE THE JUPY PARALSHIEL IN MANY TO A COMMENT

6.4 Sample Inputs/Outputs

Isolated Bodies

Input:

VINF = 890.0 ft/sec

FSMN - 0.8

RHOINF = 0.000642 lb eec^2/ft^4

ANU = 0.000575 :12/sec

D = 0.312

SREF = 0.0768 ft

NOSEL = 0.936 ft

BODYL = 3.12 ft

XMC = 2.0 ft

DELTA = 9.45 dég

NS # 50

IDCONF = 0

NAOA - 15

NTYPE = 2

NTAM = 1

AOAD = 24., 25., 26., 28., 30., 32., 34., 36.,

38., 40., 42., 44., 46., 48., 50.

RA = 0.0

GAMLIM - 100.

IOPT1 = 1

BRN - 0.0

IRUN = 0

Output:

ANGLE OF ATTACK (DEGREES)	CY	CETAMC CG- 2.00FT
24.00	0.486	1.209
25.00	0.342	0.891
26.00	0.155	0.537
28.00	-0.287	-0.255
30.00	-0.791	-0.909
32.00	-0.705	0.308
34.00	-0.241	2.254
36.00	0.251	3.872
38.00	-0.069	2.334
40.00	-0.693	0.319
42.00	-1.137	-0.774
44.00	-0.389	2.218
46.00	0.455	4.772
48.00	-0.324	1.495
50.00	-1.163	-1.341
PICKS OPTION		
ANGLE OF ATTACK (DEGREES))	CY	CETAMC CC= 2.00FT
24.00	0.694	1.728
25.00	0.489	1.273
26.00	0.222	0.767
28.00	-0.410	-0.365
30.00	-1.130	-1.299
32.00	-1.008	0.441
34.00	-0.344	-3.221
36.00	0.358	5.57.3
38.00	-0.099	3.336
40.00	-0.991	0.456
42.00	-1.625	-1.105
44.00	-0.556	3.169
46.00	0 651	6.819
48.00	-0.463	2.136
50.00	-1.662	-1.916

Body Plus Tail

Input:

```
921.0
                           ft/sec
  VINF
  FSMN
                0.8
                           lb sec<sup>2</sup>/ft<sup>4</sup>
                0.00059
RHOINF
                            ft<sup>2</sup>/sec
                0.000574
   ANU
                            ft '
                0.312
     D
                            ft^2
  SREF
                0.0768
  NÓSEL
                0.938
                            ft
  BODYL
                3.12
                            ft
   XMC
                2.0
                             ft
                9.45
  DELTA
                            deg
                  50
     NS
  IDCONF =
                . 1
                -2.709
                              ft
     XF
                 0.0
                              ft
     YF
                 0.1561
     ZF
                              f t
                -2.917
  XFMAX
                             ft
                 0.0
  YFMAX
                             ft
  ZFMAX
                 0.312
                             ft
  SREFT
                 0.049
  NAOA
                 18
                  2
  NTYPE
  NLAM
                  25., 27., 29., 31., 33., 35., 37., 39., 41.,
  ADAD
                  43., 45., 47., 49., 51., 53., 55., 57., 59.
                  0.0, 90., 180., 270.
GAMLIM
                  100.
 IOPTI
                   0
```

0

BRN

IRUN . =

OUTPUT

		1		
ANGLE OF ATTACK (DEGREES)	ey '	CETANC CG= 2.00 FT	ROLL MOM. (FT-LB)	NORMAL FORCE FIN NO. 1 (LB)
25.00	0.355	-0.820	-0.607	0.939
29.00	0.353	-1.026	-0.797	1.767
31.00	0.490	-0.484	0.001	1.120
33.00	0.767	0.376	0.116	1.208
35.00	1.013	1.171	0.487	0.594
37.02	1.190	1.856	1.199	-0.964
39.00	1.285	2.314	2.215	-3.388
43.00	0.651	2.669	-0.155	-1.884
45.00	-0.096	1.650	-0.839	-0.640
47.00	-0.804	1.111	-2.17,4	2.498
51.00	-1.315	1.445	0.374	1.705
53.00	-0.522	3.404	2.680	-0.899
55.00	0.176	4.468	3.296	-5.729
57.00	-0.238	3.576	-0.470	-1.280
59.00	-0.538	1.324	-2.087	2.631

The results of these two sample outputs, are compared against experimental data in Figures 12a and b and 13a and b

6.5 Program Limitations

There are certain limits which apply to the application of the procedures and program described in this document. Following is a list of the program limitations which the user must be familiar with before trying to use the program.

- a. The program is crossflow Mach number limited to values between0.15 and 0.8.
- b. Due to the large side wash velocities and correspondingly large fin normal forces produced when a vortex core passes close to a fin, the program has been set up to discontinue calculations at angles of attack when a vortex core passes within 1/4 body radius of a fin and proceed to the next angle of attack. The 1/4 body radius limitation was selected after comparing the results of numerous runs against experimental data.

A potential vortex model is used in the program. The velocity produced by such a vortex at a radius R is given by the following equation:

$$v_{\rm t} = \frac{\Gamma}{2\pi r}$$

It is because of this that the induced side wash velocities becomes so large when a vortex core passes close to a fin. In actuality a vortex has a viscous core beyond which the vortex can be modeled by a potential wortex. In the viscous core the velocity goes to zero at the center. In order to retain as simple a model as possible, it was decided to place the limitation described above on the program.

c. The program should only be applied to configurations which have $\emptyset = 0^{\circ}$ or 45° . This is because the program only calculates fin forces induced by the presence of an asymmetric vortex system. Only at these roll angles do the forces on the fins produced by flow conditions other than vortices cancel themselves out due to opposite senses of direction.

d. Physically it is logical that the side force induced on the finless portion of a body is contributed to by both feeding sheets and shed vortices. However, comparisons between predictions and experimental data have indicated that the best results will be obtained when the contributions from shed vortices are neglected. The program logic predictr both contributions but prior to the point at which total side force is calculated the contributions from shed vortices are set equal to zero. This is accomplished by inserting the following

SFPC (JT) = 0.0 | Side force and yawing moment induced by a shed vortex passing over a complete segment |

SFPSV (JT) = 0.0 | Side force and yaving moment induced by a vortex |

FMGPSV (JT) = 0.0 | Side force and yaving moment induced by a vortex |

shedding within the bounds of a segment

within the do-loop ending with statement 239.

These cards may be removed at anytime in order to study the effects of shed vortices on hody side forces.

e. Caution is indvised when employing the option to correct for nose fineness and bluntness ratios. The reason for this being that the scaling factors were derived from data showing considerable scatter. Also due to the unsteady nature of the vortex phenomenon, it is possible that considerably different scaling factors could be derived using other data sources.

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